

**RECONSTRUCTING THE ASSEMBLAGE OF IRON ARTIFACTS FROM THE  
LATE HELLENISTIC SHIPWRECK AT KIZILBURUN, TURKEY**

A Thesis

by

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## **ABSTRACT**

Artifacts found within the context of a shipwreck offer valuable insight into specific events surrounding a vessel's journey and also have broader implications regarding the time period of the ship's sinking. A collection of iron objects, excavated from the wreckage of a late Hellenistic ship carrying marble from the quarries at Proconnesus to the site of Claros, provides details of the implements vital to this ship's passage. It was necessary that the completely corroded and encrusted iron artifacts undergo months of conservation, in the form of replication, stabilization of the iron where it survived, and restoration before they could be cataloged and researched thoroughly.

The largest of the iron concretions was found to contain an anchor belonging to the ship. Being found on the same ship with wooden composite anchors, the iron anchor excavated at Kızılburun represents an important step in the transition in the use of wooden and lead composite anchors to their eventual replacement by anchors made solely of iron. The remaining identified objects comprise a collection of tools as well as three fasteners, all of which provide insight into the necessary equipment of an ancient wooden ship.

Within the scope of this thesis, the conservation of each iron object is detailed, and a discussion of the implements enhances the understanding of their use aboard a seagoing vessel. Further research into similar objects and the development of each tool type



offers insight into their value to the ancient seaman. Finally, a catalog of the artifacts is included, in order to provide measurements and technical drawings so that perhaps the currently unidentified artifacts can be compared to examples from other sites.

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# CHAPTER I

## INTRODUCTION

### THE KIZILBURUN COLUMN WRECK

In 2005, the Institute of Nautical Archaeology (INA) at Texas A&M University began the excavation of an ancient cargo ship, which was wrecked off the rocky coastline of western Turkey, near the present-day city of Izmir. The project was carried out under the direction of Dr. Deborah Carlson, president of INA, and Dr. Donny Hamilton, both professors in the Nautical Archaeology Program within the Department of Anthropology at Texas A&M University. The promontory where the ship sank is called Kızılburun, Turkish for 'Crimson Cape.' The location has proven to be a dangerous point for ships, as there are at least five shipwrecks clustered around the promontory, all from different time periods.<sup>1</sup> One of the earliest wrecks lies at a depth of 45 meters. Known as the 'Column Wreck,' it is a late Hellenistic stone carrier laden with approximately 50 tons of marble architectural pieces, including eight massive marble drums and a capital, components of most of a single column in the Doric style (Fig. 1.1).<sup>2</sup> Given the size of the drums, there is little doubt that the column was meant for a temple, and since the architecture belonging to the Doric order was out of fashion at the time of its sinking, the column on the Kızılburun ship seemed to have been intended as a repair or an attempt to complete the construction of a previously unfinished temple.<sup>3</sup> Having sourced the drums

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<sup>1</sup> Pulak and Rogers 1994, 18-20.

<sup>2</sup> Carlson and Aylward 2010, 145.

<sup>3</sup> Carlson 2007, 9.

to the quarries at Proconnesus, an island in the Sea of Marmara, the destination of the ill-fated ship was almost certainly the Temple of Apollo at Claros.<sup>4</sup>

Approaching the promontory from the south, it is understandable why it would have been dangerous. The tip of the cape juts menacingly out to sea and seems uninhabitable due to its craggy shoreline. The shore nearest the wreck site, and where the excavation camp has been established, faces south. This left the excavation team vulnerable to the *lodos*,<sup>5</sup> or the precarious southerly wind, which even now forces the projects' ships to seek refuge. Often, the *lodos* blows in with little warning; quickly transforming the calm breeze to strong gusts of wind and the inviting blue water to a choppy, unforgiving sea. It leaves one with a sense of what ancient sailors faced when navigating this particular strip of coast.

When the ship was lost, it was carrying stores and personal effects of the crew necessary to complete the journey, in addition to the main cargo of marble. A collection of a couple dozen amphoras of different types, Lamboglia 2, Koan, Rhodian, Knidian, and Colchian, support the late Hellenistic date for the sinking of the ship.<sup>6</sup> Scattered among the ceramics and marbles, dozens of iron artifacts, completely obscured by heavy concretion, were brought to the surface after two millennia in the salty Aegean. Their identities would remain a mystery until further analysis in the laboratory could be

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<sup>4</sup> Carlson 2009, 12-13 and Carlson and Aylward 2010, 150-4.

<sup>5</sup> Carlson 2005, 3-4.

<sup>6</sup> Carlson 2007, 4.

completed, revealing the function of each and shedding light on their significance to the ship's final voyage.

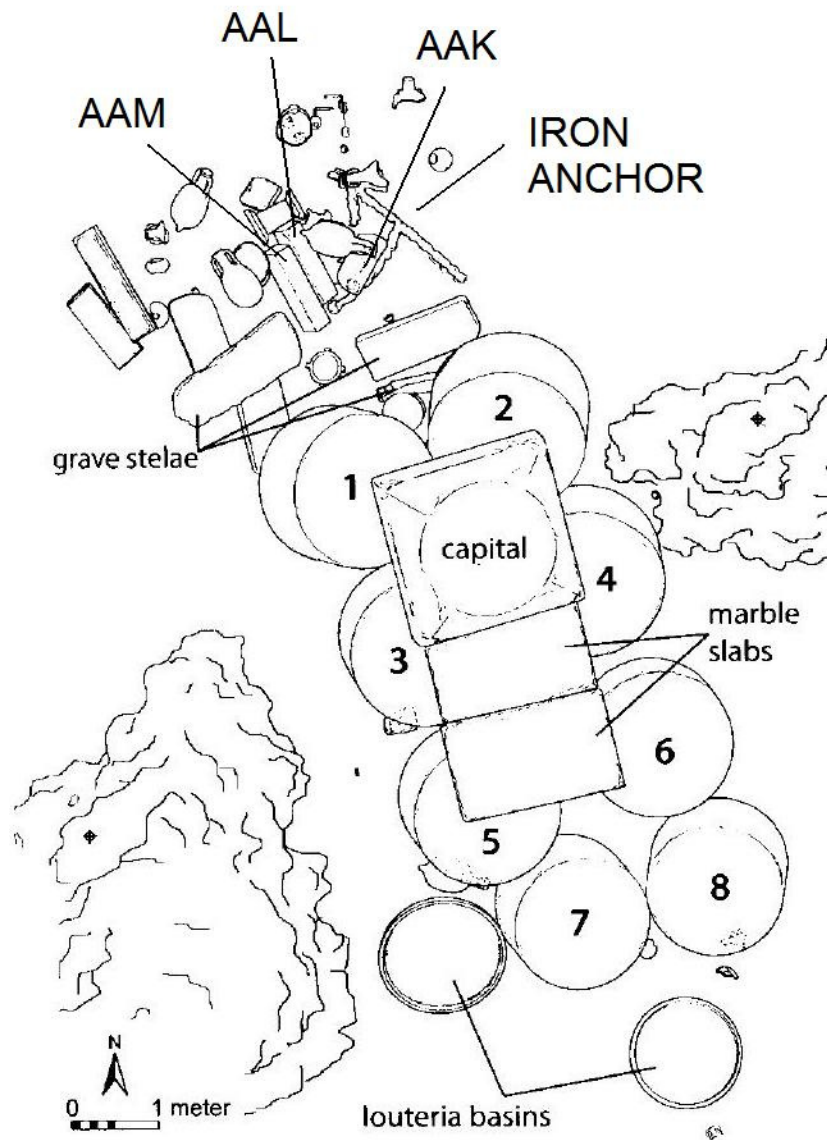


Fig. 1.1: Plan of the Kızılburun shipwreck in 2005 before the first season of excavation (from Carlson and Aylward 2010, Fig. 3; drawing by S. Matthews, used with permission from INA).

## THE IRON OBJECTS

During the 1993 INA survey conducted by Dr. Cemal Pulak from Texas A&M University, the Kızılburun Column Wreck was first located, and a large iron object came to light. Pulak recognized a substantial artifact near the column drums as an iron anchor.<sup>7</sup> The site and the anchor were further explored in another survey at the site in 2001, led by Tufan Turanlı.<sup>8</sup> From the beginning of the excavation in 2005, strange rock-like aggregates, known as concretions, and remnants of iron objects were detected at the site. Of the many specimens raised, most were iron flakes and bits of encrustation that had broken away from larger artifacts. Fifty-one lots suspected of being iron objects were closely examined and x-rayed, and from those, 31 were found to contain evidence of legitimate objects. Following conservation and joining of broken concretions, a total of 20 artifacts were identified. The largest object was the ship's iron anchor, complete with its stock and cable ring, a rare and encouraging find. Additionally, an iron anchor tooth reinforced the arm of one of the ship's wooden anchors, the implications of which will be discussed in a later chapter. A collection of tools including a nail remover, a double axe, an axe-adze, and two chisels were important implements for the crew, and three fasteners intimate details of the ship's construction. Several additional artifacts remain unidentified. This assemblage represents a variety of aspects in the life of a seagoing vessel: initial construction, maintenance of the wooden hull, shipboard activities, and the safe passage of the ship.

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<sup>7</sup> Pulak and Rogers 1994, 19.

<sup>8</sup> Turanlı 2001.

While the smaller objects were excavated and removed from the seabed with relative ease, the excavation of the iron anchor (AN 1), being so large, took several weeks while its position was carefully mapped. Its association with other nearby objects was also documented thoroughly, since its identity and purpose were not yet determined with certainty. The diligence with which the excavators recorded important on-site details, discussed below, allowed a faithful reconstruction of AN 1 in the laboratory.

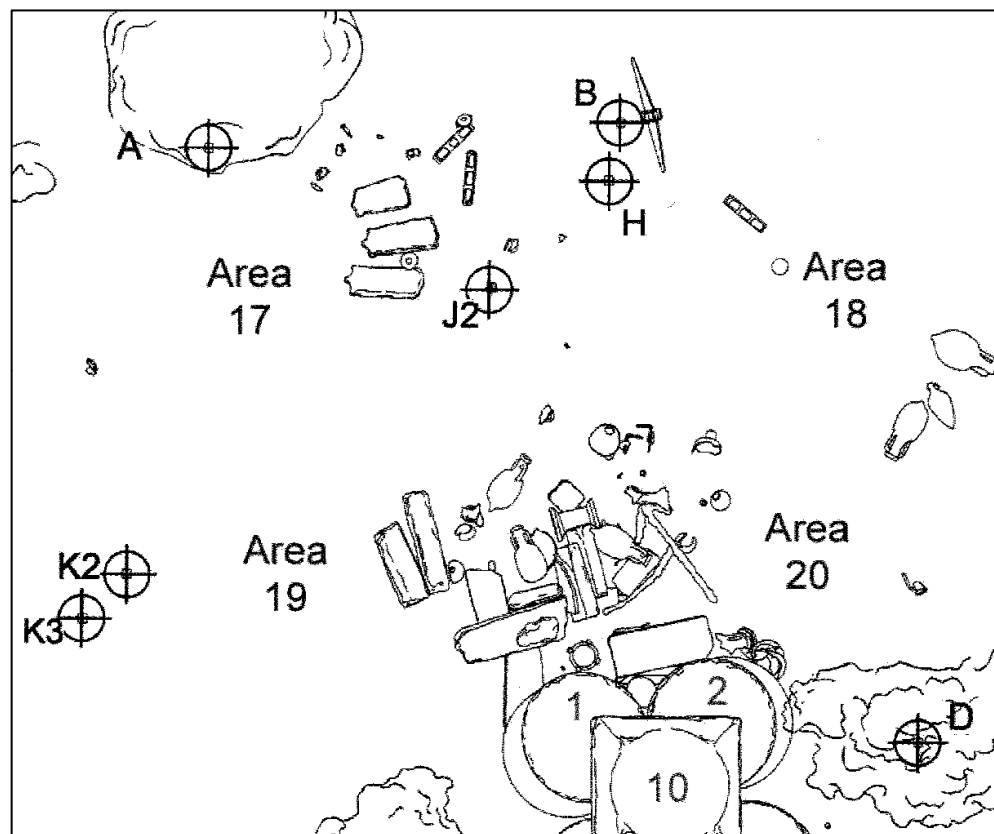


Fig. 1.2: Portion of site plan showing anchor and upslope area of wreck site divided into quadrants (after Carlson 2007, Fig. 1; drawing by S. Matthews, used with permission from INA).

### *Excavation of the Anchor*

When the excavation began in 2005, a site plan was produced, showing a portion of the shank visible on the surface of the sand, although at the time, the identity of the artifact had not been verified. Each of the column drums was given a unique designation, numbers 1 – 8, and the upslope area was divided into four quadrants, areas 17 – 20, with the odd numbers on the western half of the site and the even numbers on the eastern half (Fig. 1.2). **AN 1** was found in area 20, just upslope of Drum 2. As it was being excavated, a large protrusion was unearthed perpendicular to the shank, intersecting it near its middle. Identification of concreted iron objects is practically impossible on site, and during excavation it was theorized that this system of concretions was one piece of equipment, such as a bilge pump or part of the lifting mechanism for the drums. Only after the sections were studied in the lab was it decided that the two perpendicular pieces were two separate objects, representing the anchor and its detachable stock (**ST 1**).

The first note of the anchor concretion in the divers' logs occurred 27 June 2005 when Dr. Faith Hentschel noted the presence of the large metal shaft in area 20 (Fig. 1.3). Her initial thought was that the object was an intrusive Byzantine anchor of the cruciform type found on the Yassiada 7<sup>th</sup>-century C.E. shipwreck, but with broken arms.<sup>9</sup>

Preliminary measurements were taken in situ. The overall length was recorded at 1.7 m, and the maximum preserved arm span measured 1.0 m. The team had hoped to raise the object intact by sliding it onto a tray, which was made difficult by the large concretion

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<sup>9</sup> van Doorninck 1982, 124 Fig. 6-8.



globules on the undersides of each section, or consolidating it first, but after substantial breaks in the concretion were discovered, the conservator on site decided it would be best to raise the individual pieces separately. Artifacts determined to be significant objects of reference remaining on the seabed for some time before being lifted, including intact amphoras and various marble pieces other than the drums, were given a unique three-letter designation. Being that the concretion was so substantial, it was designated ABX. Each section was given its own lot number as it was raised as well as a sub-number of the ABX designation (ABX-1, ABX-2, etc.), in order of removal from the seabed.

On 26 July 2005, the first section of the concretion was raised. ABX-1 (Lot 205) consisted of the portion nearest Drum 2. That same day, the perpendicular extension was discovered. This “arm,” so-called in contemporaneous dive logs, extended beneath the lower edge of an adjoining marble block, AAK (Fig. 1.4). Given this association, it seemed probable that the iron concretion was part of the cargo or machinery and not intrusive as initially proposed. It was also postulated that the concretion and the extension represented two anchor shanks perpendicular to each other. At a depth of 45 meters, bottom time was limited to 20 minutes of work per dive, which leaves very little time for on-site evaluation. At such an early stage in the excavation, no idea was discredited.

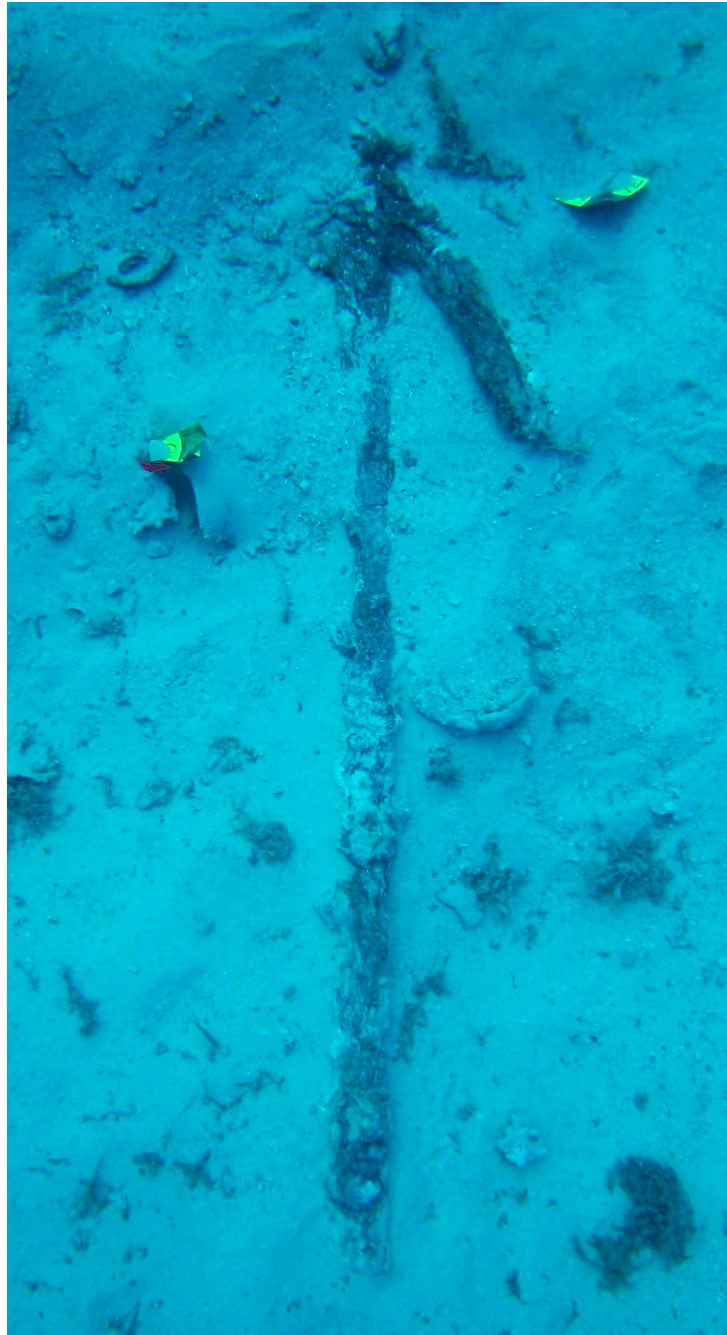


Fig. 1.3: The initial exposure of the anchor concretion in situ on 9 July 2005 (photo by D. Carlson).



Fig. 1.4: During the excavation of the perpendicular extension and following the removal of section ABX-1 from the anchor concretion on 27 July 2005. Marble block AAK is visible at left (photo by D. Carlson).

Another interesting piece relating to the main anchor shaft was uncovered on 28 July 2005. It was a small bulbous concretion, not connected to ABX, but in line with it. Assigned Lot 311, the relationship of the object to the anchor was unclear. It was lying 10.0 cm downslope of the end of the concretion (ABX-1). Further excavation on this day revealed that the large extension piece perpendicular to the anchor continued downslope of block AAL and partially beneath block AAM.

The right arm of the anchor, designated ABX-2 on 30 July, was found to be separated from the rest of the body of the concretion. It was raised on 1 August as Lot 261.

Hentschel noted numerous amphora body sherds as well as fineware sherds beneath ABX-3, the left arm, and made the observation that the extension was concreted to both blocks AAK and ABZ, presumably implications of turmoil during the ship's sinking. In addition, she observed that in association with the piece, there were many copper nails, the positions for which seem to be significant and were recorded.

August 3 marked the beginning of concentrated clearing of ABX-3, the piece which included the anchor's crown and left arm, with fragments of planking concreted to the underside of the arm. That day also signified the excavation of ABX being handed over to Dr. Ken Trethewey, coinciding with Hentschel's departure. The following day, divers were able to raise ABX-3 as well as ABX-4 under the same lot number, Lot 283. Block AAK was successfully raised as well, clearing the way for further investigation of the stock. Divers noted many artifacts in close association with the anchor, including ceramics nearby, nails beneath it, and marble blocks on top of it, all carefully documented prior to removal.

For the next two weeks, divers worked on the portions still in situ, which included some of the largest and most cumbersome fragments of the concretion. On 13 August, Trethewey uncovered more nails associated with the extension, noting that they were situated vertically with the heads down in the sand and possibly attached to the

concretion. Four days later, he was able to raise ABX-5, ABX-5a, and ABX-6. ABX-5 (Lot 367) was the central part of the anchor's shank and the largest fragment of the concretion. ABX-5a (Lot 367.01) was a small bulbous concretion attached near the midpoint of the shank, and ABX-6 (Lot 370) was the portion of the extension which attached to ABX-5. August 18 marked the removal of the final two pieces from the sea floor: ABX-7 (Lot 386) and ABX-8 (Lot 387), which constituted the middle and westernmost end of the extension, respectively (Fig. 1.5).

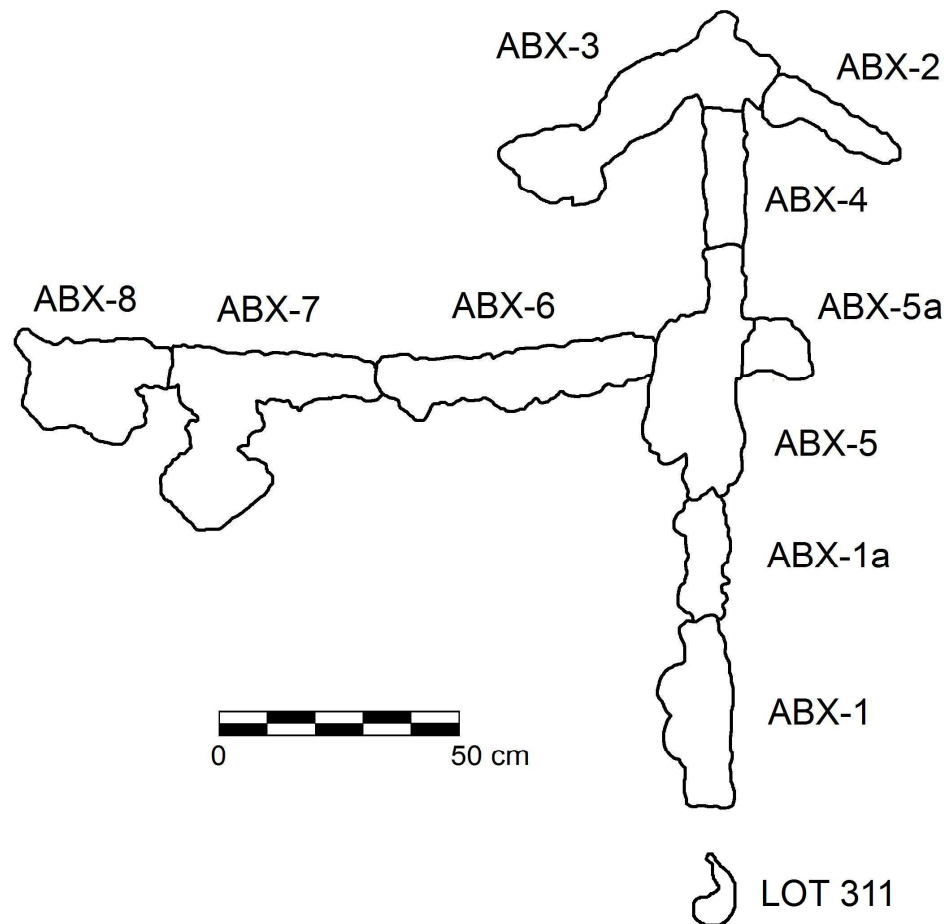


Fig. 1.5: Sections of ABX and Lot 311 as they appeared on the seabed.

## THE CORROSION OF IRON UNDER WATER

“Nature, in conformity with her usual benevolence, has limited the power of iron, by inflicting upon it the punishment of rust.”<sup>10</sup> Pliny's description, dating to the 1<sup>st</sup> century C.E., conveys a longstanding knowledge of iron's main weakness: the tendency toward corrosion. In order to rediscover the identities of obscured iron objects, it is necessary to first understand what forces contributed to their present state. Once deposited in a marine environment, iron corrodes at a much faster rate than iron on land.<sup>11</sup> Water behaves as an electrolyte, encouraging the loss of ions from the artifact into its surrounding environment, thus encouraging deterioration.<sup>12</sup> The soluble salts in seawater, being charged, can conduct an electric current and therefore facilitate electrochemical corrosion.<sup>13</sup> The metal forms a hard shell of concretion composed of calcium and magnesium carbonate, hydroxide, precipitates from the salt water, and oxidized iron, which migrates away from the metal as it corrodes. This encrustation engulfs any other adjoining object such as seashells or archaeological material, which explains their common presence within the concretion matrix. The rock-like material forms a seal around the deposited iron, where oxidation begins at the surface and continues into the core of the artifact, leaving in its place a hollow where the object once existed (Fig. 1.6). This cavity reflects the original dimensions of the iron object, in effect preserving it, since the hollow can be used as a natural mold to produce an

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<sup>10</sup> Plin. *HN* 34.40.

<sup>11</sup> Cronyn 1990, 171.

<sup>12</sup> Cronyn 1990, 18-19.

<sup>13</sup> Cronyn 1990, 23.

accurate replica of the lost object.<sup>14</sup> The process of replicating iron tools from this cavity was pioneered in the 1960s by Michael Katzev and Frederick van Doorninck and has become the standard by which encrusted iron objects from marine sites are treated.<sup>15</sup>

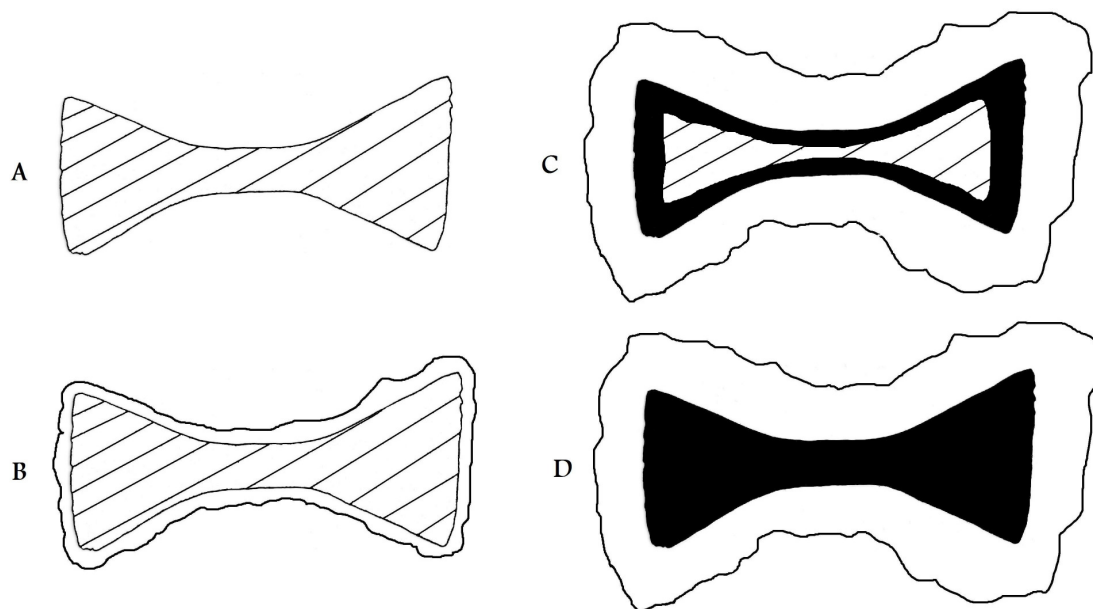


Fig. 1.6: Corrosion of iron and the formation of an encompassing concretion. A. Iron object remains metallic following deposition. B. Concretion layer begins to form at surface. C. Concretion thickens while iron begins to degrade. D. Iron completely reduced to black powder corrosion product within dense concretion but surface of object retains shape (drawing by author).

In the case of most of the iron artifacts from Kızılburun, oxidation has occurred as explained above, resulting in a hollow, amorphous, concreted mass. Only after the excavation of one particular concretion, which was noticeably more dense than other objects of comparable size, was it discovered that not all the concretions were hollow.

<sup>14</sup> Cronyn 1990, 181-5.

<sup>15</sup> Katzev and van Doorninck 1966, 135-40.

Iron corrosion in water is a complicated process and not at all uniform. After 2000 years, it can be assumed that most iron has long ago disappeared. Active corrosion occurs when ions migrate away from the metal toward its deposition environment, leaving the object vulnerable to further decay. This process is behind the formation of a concretion and the total loss of original metal resulting in an inner hollow, as described above. Occasionally, however, some iron remains metallic within its concretion, and another explanation must be considered for the reasons behind its survival. Passivation occurs when ions from the object react with anions in the environment to form a protective layer, shielding the artifact from further corrosion, which usually depends on the pH as well as energy found at the site,<sup>16</sup> for example the energy of the varying currents at Kızılburun. Unfortunately, a summation of the processes leading either to corrosion or to survival is not that simple, since not all of the contributing factors facilitating deterioration are known,<sup>17</sup> especially for a period of time spanning two millennia. Upon discovering an artifact that has somehow avoided deterioration, it can be assumed that the usual factors guiding an object toward corrosion are absent,<sup>18</sup> or that the metallic object may be intrusive on a site where most other iron corroded. In the following chapters, each object is discussed with regard to its individual state of preservation and what steps were taken to conserve and reconstruct it.

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<sup>16</sup> Cronyn 1990, 167-8.

<sup>17</sup> Doménech-Carbó et al. 2009, 127.

<sup>18</sup> Cronyn 1990, 17.



## CHAPTER II

### THE IRON ANCHOR

The most visible of the iron artifacts found on the Kızılburun shipwreck was a large, T-shaped concretion. There were many initial theories regarding the identity of this particular artifact, including a bilge pump or part of a mechanism on board the ship that aided the lading of the vessel's marble cargo; however, reconstruction of the object in the laboratory in the summer of 2008 verified Dr. Pulak's initial observation. The large concretion held a complete iron anchor, including the detachable stock.<sup>19</sup>

#### ANCHOR TERMINOLOGY

There are several key components and terms of ancient anchors, some of which disappeared through the centuries while making room for new developments in anchor design and manufacture. The features discussed here are pertinent to anchors in use in the Late Hellenistic Period (Fig. 2.1). Beginning at the head of the shank, there is the ring aperture, a hole through which a ring passed making it possible to hoist and lower the anchor. The stock aperture, a rectangular slot through which a detachable stock passed and was affixed to the anchor, occurs below the ring aperture. The main body of the anchor is called the shank. Two arms protrude from the shank, and each comes to a point (the tooth). In this case, the two arms join and form a V-shape at the lower end of

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<sup>19</sup> Preliminary analysis of anchor published in Carlson and Hamilton 2009 and Rash 2010; readdressed here with permission from INA and the Center for Maritime Archaeology and Conservation (CMAC).

the anchor, called the crown. Another ring aperture at the crown is meant for a ring through which ran an additional line to disengage the anchor from the seabed.<sup>20</sup>

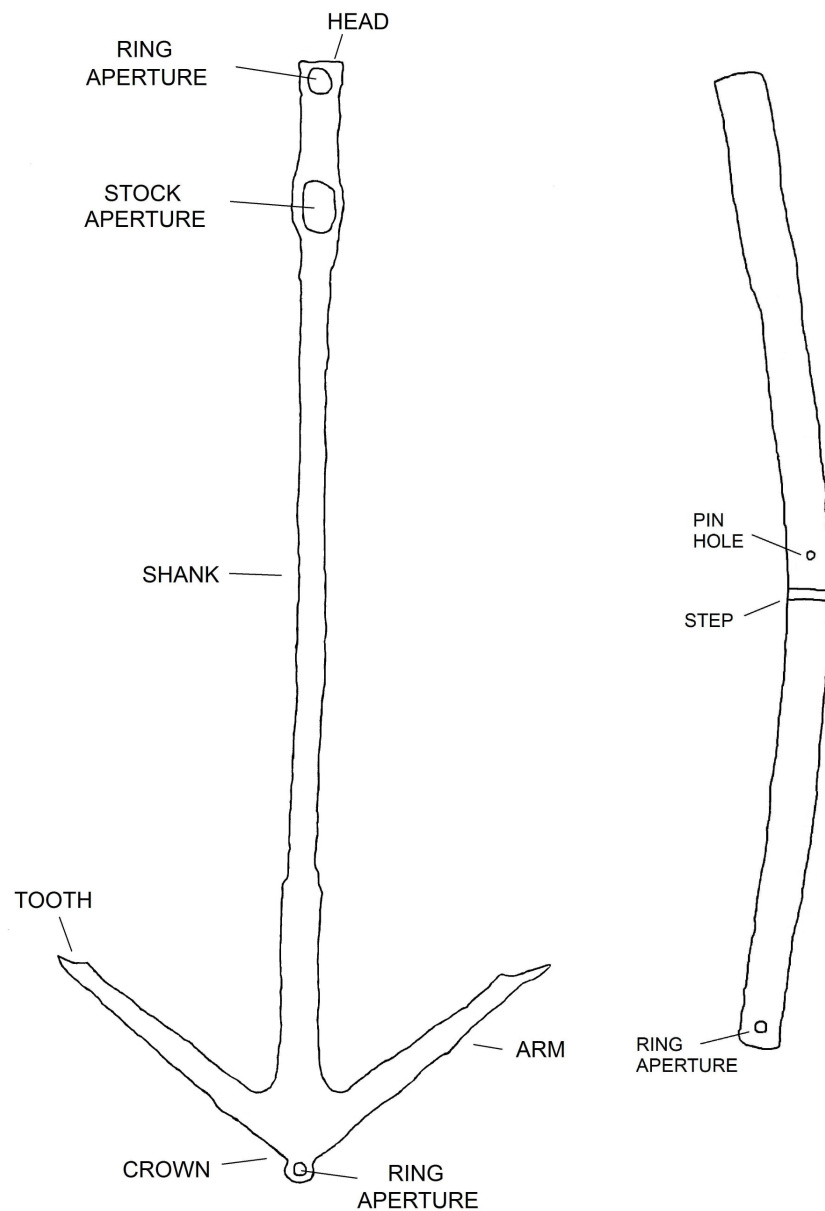


Fig. 2.1: Components of an ancient iron anchor (left) and its stock (right) (drawing by author).

<sup>20</sup> Terminology from van Doorninck 1982 and 2004.

The stock is a detachable piece of equipment that passes through the anchor's shank on a 90° angle from the arms, thus ensuring the teeth grip firmly and preventing the anchor from lying flat on the sea floor.<sup>21</sup> A step occurs approximately midway along one face of the stock, which rests against the anchor when affixed.<sup>22</sup> A pin, permanently attached to the step with a chain, is inserted into a hole opposite the step to firmly hold the stock to the anchor.<sup>23</sup> Some stocks have an additional aperture for another ring to aid in lifting the anchor.

## PRELIMINARY ANALYSIS

In the summer of 2008, the team took a break from excavation to conduct a study season on artifacts raised thus far. The concretion fragments excavated in 2005 were removed from wet storage and reassembled using the divers' logs and were reconstructed accordingly on the floor of Nixon Griffis Conservation Laboratory with INA's Bodrum Research Center and photographed as they would have been in situ (Fig. 2.2). Doing this on a flat surface created a challenge since the pieces had amorphous concretion blobs attached to the undersides, which had been cushioned by the sandy seabed.

Although the concretion was comprised of many separate pieces, overall, it was in good condition: most of the breaks joined cleanly to each other, and reassembly proceeded following the divers' descriptions. Typical of iron concretions, color ranged from dark brown to red and even white, the latter being crumbly and very brittle and only on the

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<sup>21</sup> Haldane 1990, 20-1.

<sup>22</sup> Kapitän (1984, 38-40) discusses this in relation to wooden anchors with lead stocks as a precursor to iron.

<sup>23</sup> Galili et al. 2010b, Figs. 5 and 6.

outermost layer of the concretion matrix. During this initial reconstruction in the laboratory in early June 2008, it was unmistakably clear that this enormous system was a Hellenistic iron anchor.



Fig. 2.2: The author reconstructing the system of concretions in the Nixon Griffis Laboratory in Bodrum, Turkey in August 2008 (from Carlson and Hamilton 2009, Fig. 1; photo by J. Littlefield, used with permission from INA).

Each concreted fragment was sketched in detail to provide an idea of the shape and extent of the encrustation (Fig. 2.3). The drawings were useful in studying the change in shape of the actual anchor and how that was reflected in the cross-sections of the concretion fragments. Measurements were noted for the individual sections including the overall length, the maximum width, taken across the top of each fragment as it appeared on the seabed, and the thickness. At every break between sections, the object void was measured, (Table 2.1), and in some cases the cross-sectional shape could be

described as either distinctly rectangular or octagonal, characteristics important in determining the approximate age of the anchor.

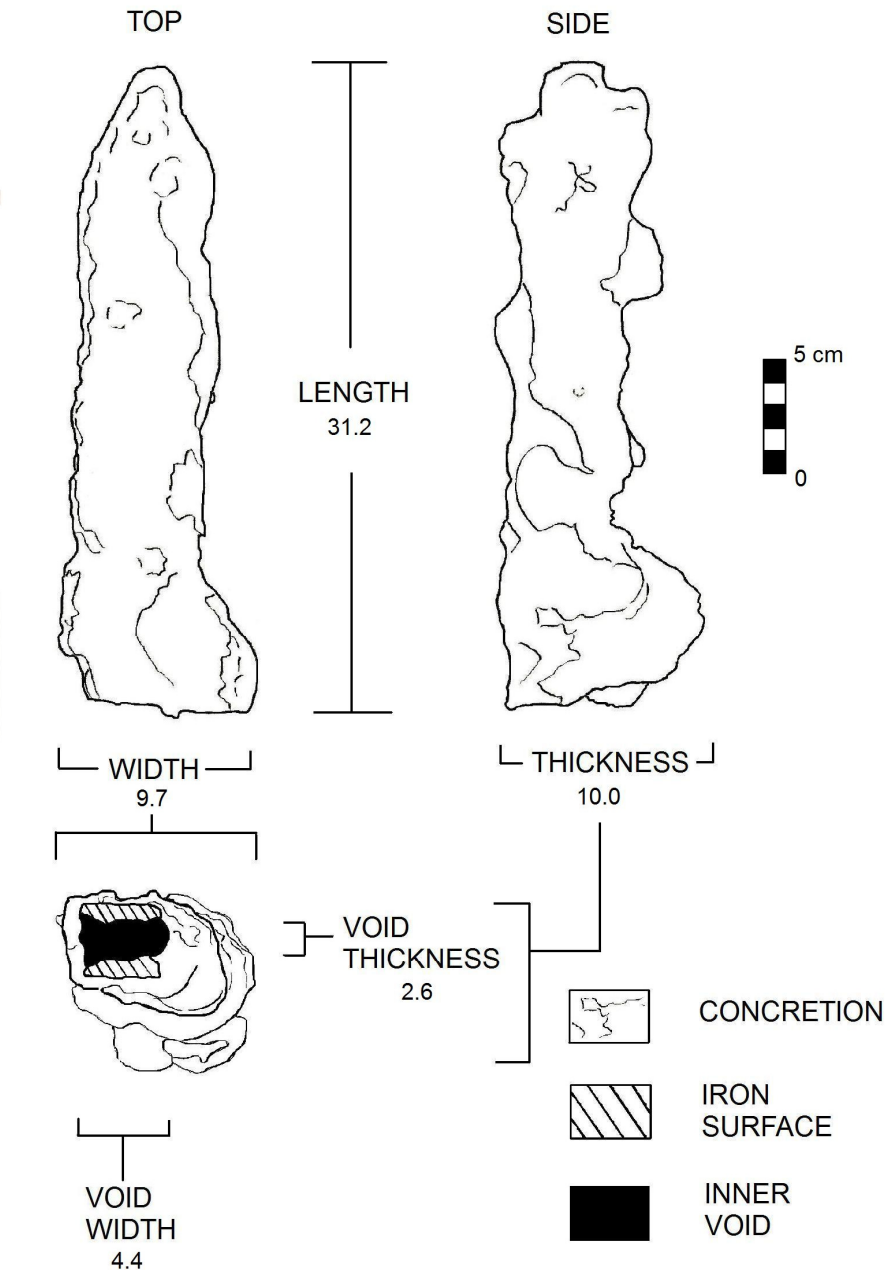


Fig. 2.3: Example of drawing for concretion section ABX-2 and how measurements were taken. Dimensions in cm (drawing by author).

	<b>ABX-1</b>	<b>ABX-1a</b>	<b>ABX-2</b>	<b>ABX-3</b>	<b>ABX-4</b>	<b>ABX-5</b>	<b>ABX-6</b>	<b>ABX-7</b>	<b>ABX-8</b>
<b>Dimensions</b>	Upper Shank	Shank	Right Arm	Left Arm and Crown	Shank	Shank	Stock	Stock	Stock
Length	37.2	26.8	31.2	57.4	33.6	55.2	58.4	45.4	36.6
Max W	16.0	10.6	9.7	20.2	8.5	20.1	13.6	36.6	21.8
Max TH	10.8	10.8	10.0	---	17.8	21.4	---	---	---
W at Upper Break	---	6.8	---	8.6	8.4	8.2	7.8	8.3	---
TH at Upper Break	---	8.3	---	6.9	6.3	6.3	5.0	5.9	---
W of Inner Void	---	4.0	---	6.0	3.3	4.1	5.9	5.8	---
TH at Inner Void	---	4.5	---	2.3	3.5	3.8	2.8	3.5	---
W at Lower Break	8.2	6.1	9.7	9.5	8.7	8.4	9.3	9.3	8.3
TH at Lower Break	6.2	6.5	9.0	7.9	5.8	8.1	9.8	7.5	5.6
W of Inner void	3.5	4.4	4.4	5.4	5.8	3.7	6.4	7.0	6.1
TH of Inner void	3.4	4.4	2.6	2.8	1.3	3.9	2.2	4.0	3.6
W at Side Break	---	---	---	---	---	8.2	---	---	---
TH at Side Break	---	---	---	---	---	5.7	---	---	---
W of Inner Void	---	---	---	---	---	6.2	---	---	---
TH of Inner Void	---	---	---	---	---	3.1	---	---	---

Table 2.1: Dimensions for concreted sections of ABX. For sections of anchor (ABX-1 through ABX-5), the lower break is the break nearest the crown when reconstructed, and for the anchor stock (ABX-6 through ABX-8), the lower break is the break nearest the anchor, as it was lying on the seabed. ABX-5 was the only section with a third break, on the side of the concretion, where it connected to ABX-6. Dimensions in cm.

### *The Anchor*

During this initial cataloging process, it was discovered that there were more sections present than there had been in the field. ABX-1, the uppermost portion of the anchor, originally in one piece, was in two pieces when studied in the laboratory (Fig. 2.4). The largest section remained ABX-1 while the smaller of the two was given the label ABX-1a to distinguish the two sections from each other in note-taking during the conservation process. Although detached, ABX-1a joined very snugly to breaks in both ABX-1 and ABX-5. ABX-1 had a small indentation, thought to be a hole intended for the attachment of a ring, as well as a rectangular hollow, which appeared to be the heavily concreted opening meant to hold the detachable stock, penetrating the concretion. In addition, the iron had developed large globular encrustation on the underside, which was hoped to contain remnants of the anchor's ring.



Fig. 2.4: ABX-1 (left) and ABX-1a (right).

ABX-1 and ABX-1a at first sight appeared complicated as well as diagnostic, being that the cross-sections of the two concretion sections forming the very top of the anchor were vaguely hexagonal or octagonal in cross-section, as was the break joining ABX-1a to ABX-5. Recalling the bronze anchor on display in the Bodrum Museum of Underwater Archaeology, it seemed that this could be an important piece of information in identifying this anchor type. The colossal bronze anchor has an octagonal cross-section through its midsection, although through the upper shank and near the juncture of the arms and crown, the section changes to a rectangular shape. It seemed that the Kızılburun anchor mimicked the Bodrum bronze anchor in that regard. Both ABX-1 and ABX-1a were full of sediment but appeared largely hollow, in that the only metal remaining were the exterior layers of the anchor's surface.



Fig. 2.5: ABX-5, in profile, showing detail of connection to anchor stock (ABX-6) (photo by J. Levin).



ABX-5 (Fig. 2.5) was the conjunction of the anchor and the stock, and because of the intersection of so much iron, the concretion around this piece was substantial.<sup>24</sup>

Studying ABX-5 more closely, it was clear that the anchor and stock abutted, with the stock concreted to the underside of the anchor shank. The cross-section at the break joining ABX-4 revealed a combination of corrosion and concretion within the break: a dense concretion layer, a sandy layer, and a metallic layer. The distinct facets of the octagonal shape were also visible in the interior. Although it was open at both ends, there was sand densely compacted in the innermost areas of the void.



Fig. 2.6: ABX-4, with wood remains visible on largest protrusion.

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<sup>24</sup> ABX-5a was discarded after an x-ray proved that it was an exterior fragment of this immense concretion and contained no further objects.

ABX-4 (Fig. 2.6) was a smaller portion of the anchor's shank and was attached to ABX-5. Its cross-sections were again diagnostic in that where it connected to ABX-5, the shape appeared octagonal, but where it joined ABX-3, the cross-section was rectangular. There was substantially less sediment at the ABX-5 joint as well, making it easier to see the inner wall of the void, and although difficult to define in places, there seemed to be metal lining the interior. Like the other fragments, it was packed with sediment, although it was possible to see through the length of the concretion via a very small hollow. Two large unidentified concretion nodules formed on the underside of the section, and it was thought that they were a result of heavy concretion and not key to the identification of the artifact.

There were two nails attached to the underside of the section as well, although it seemed that their attachment occurred as a result of being caught in the anchor's immense encrustation, and that they did not serve a function in relation to the anchor itself. There was wood, or the imprint of wood, concreted to the underside of the largest nodule – the portion that was buried deepest in the sand. It was near this imprint that a third nail was noted, indicating that the wood and nail were likely associated and probably indicative of hull remains.<sup>25</sup>

ABX-3 was another very heavy, substantial piece, containing the crown and the left arm

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<sup>25</sup> The diameters of the three copper nails were very consistent, ranging from 0.5-0.7 cm.

of the anchor, as it was lying in situ (Fig. 2.7). The iron corrosion preserved a large fragment of wood on the underside of the arm at the tooth and a smaller fragment midway down the same arm. There were also two fineware ceramic sherds attached to that arm, one medium and one tiny. The medium sherd was newly broken and contains a portion of the vessel's rim, and the smaller sherd is painted with a faintly visible pattern. Within this segment, the sediments were densely packed, but it seemed there might be fragments from the surface of the anchor within the concretion when loose chunks of iron were found to be detached from it. The length of ABX-3, measured from the crown of the anchor to the tip of the still-attached arm, was 57.4 cm.



Fig. 2.7: The underside of ABX-3, with visible wood, nail, and ceramic fragments (photo by J. Levin).



Fig. 2.8: ABX-2.

Finally, ABX-2 (Fig. 2.8) was the most manageable section, and thus one of the first to be raised from the seabed. It is the right arm, broken away from ABX-3 very near the crown. Within the break, iron remains were found lining the upper and lower surfaces of the void. As with the other sections, there was thick concretion on the underside, consisting of white crumbly material made of loosely packed sand and small seashells.

#### *The Anchor Stock*

The identity of the anchor stock was very puzzling during excavation in 2005. On site, it was thought that it might be another anchor shank lying perpendicular to the one on top of it; however, that was the extent of the concretion, in that there were no arms, nor further breaks to suggest that there might have once been arms. Upon drawing and photographing the sections comprising the extension in 2008, it was decided that that portion must be the stock belonging to the anchor overlying it. This possibility was



supported by the fact that the bronze anchor stock in the Bodrum Museum has a pronounced curvature (Fig. 2.9), explaining the curvature visible in the adjoining sections ABX-6, ABX-7, and ABX-8. It was also verified by studying the shape of the cross-section of the fragments in the laboratory in 2008. It had no indication of a change in shape, as seen in the anchor, and remained rectangular throughout.



Fig. 2.9: Bronze anchor from the Bodrum Museum of Underwater Archaeology, with associated stock (right) showing clear curvature (photo by J. Littlefield).

The section nearest ABX-5 was labeled ABX-6, which cleanly joined both the cavity in the underside of ABX-5 and section ABX-7. Upon inspection of the fragment, it was discovered that ABX-6 had a slight curvature, which appeared more pronounced in this lone section, since it made up the longest continuous portion of the stock. Again, like the other pieces, there were irregular globular concretions on the underside of it, which in this case also contained concreted fragments of four separate nails. The nails were made of copper, recognized by the green staining, and were similarly oriented: they were head down into the sand in situ, as the portions of the nails preserved in the ABX-6 concretion matrix were only the double-clenched tips. The orientation of the nails confirmed that they were planking and framing nails still attached to the wood during the corrosion of the anchor, and a study of the placement of the nails might allow some speculation of the nail patterns of the ship.<sup>26</sup> Additional concretion nodules held small impressions of wood, which due to the visible wood grain left behind, attested to the presence of longitudinal hull planking in close proximity to the anchor.

The breaks fit snugly together, which would be beneficial for casting, and made reconstruction very straight-forward. One nail protruded from the underside of ABX-6 near the break joining ABX-5. The green color again was indicative of copper, and investigation into the divers' notes revealed that another portion of the nail was raised independently of the stock. Small sections of metal were noted, although very thin and heavily concreted, even on the interior of the cavity. These inner concretions

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<sup>26</sup> Littlefield 2012.

substantiate the idea that the outer encrustation had been broken for some time and that the massive sand deposits within it further contributed to the degradation of the surviving metal, sloughing it off in places, while allowing for the accumulation of concretion in others.



Fig. 2.10: Wood remains attached to ABX-7 and what appears to be a peg (photo by J. Levin).

ABX-7 comprised the middle section of the stock, between ABX-6 and ABX-8. There was a very large projection on the underside, consisting of extensive encrustation which penetrated the wooden planking. The planks ran perpendicular to the stock, which would denote a north-south orientation for the wood itself, suggesting it was longitudinal



planking. Within the concretion, the planking left an impression, along with impressions of a seam between two planks as well as a peg, characteristic of mortise and tenon joinery (Fig. 2.10). There was also one ceramic fragment preserved in the concretion. The substantial encrustation surrounding the wood remains was closely examined for additional artifacts, such as nails or ceramics, and object voids indicative of other iron artifacts, but none were found. Metal remnants within the break between ABX-7 and ABX-8 were very loose, and some fragments became detached during initial inspection.



Fig. 2.11: The underside of ABX-8 (photo by J. Levin).



The terminus of the stock was ABX-8. It was a smaller section, and its globular shape can be attributed to the end of the iron corroding downward toward the planking of the ship, a portion of which was still attached to its underside (Fig. 2.11). There was also a small projection at one end, perhaps another object, but its identity remained unknown until mechanical cleaning could commence. Being that the concretion was so dense, it was difficult to attain a decent x-ray image of this section, so cleaning proceeded cautiously.

## CONSERVATION

After examining the sections thoroughly in the laboratory, it was clear that the iron had corroded almost entirely, thus leaving an empty cavity which would serve as the mold for the object. Due to breaks occurring in situ, there was very little black powdery corrosion product inside the cavities, as often exists with other whole concretions. Over the centuries, the activity of currents packed sand into these cavities, thus the iron surface, which is essential in producing an accurate replica, was in poor condition, having been effectively exfoliated by two millennia of moving sand particles. Ideally, the remaining exterior surface is kept intact during cleaning, in order that the dimensions of the cast more accurately reflect the dimensions of the original object.

Another benefit arising from the survival of the original surface is that any markings from manufacture, such as welding seams, might still be present giving an idea of how many pieces of iron were used, information gathered during a careful study of the

anchors from the 11<sup>th</sup>-century C.E. shipwreck at Serçe Limanı, Turkey.<sup>27</sup> However, the surface of the Kızılburun anchor was incredibly flaky, fugitive, delicate, and problematic during conservation. It was necessary to fully remove the internal sand to produce a good cast, and this led to further degradation of the iron, as it seemed in places that the sand was the only thing holding the original surface layers in place (Fig. 2.12).

All of the nine sections were full of sediment but seemed hollow, in that the only metal remaining was in the outermost layers of the anchor's surface. To confirm this, the fragments were taken to the Bodrum Özel Hospital, where the gracious radiology department staff x-rayed each section carefully and patiently. Using digital x-ray technology, excellent images of the inner spaces of the concretion were produced, which made it much easier to understand how casting should be executed (Fig. 2.13). X-ray images are helpful when first deciphering what is contained within each segment. The densest concretions, as well as any iron remains, appear as bright white spots, and cavities appear black with a white outline showing the contours of the original object. Thus, the x-rays confirmed that there was no metal within the cavities, except for a thin outer lining, and that the casting process would be fairly straight-forward.

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<sup>27</sup> van Doorninck 2004, 193-5.

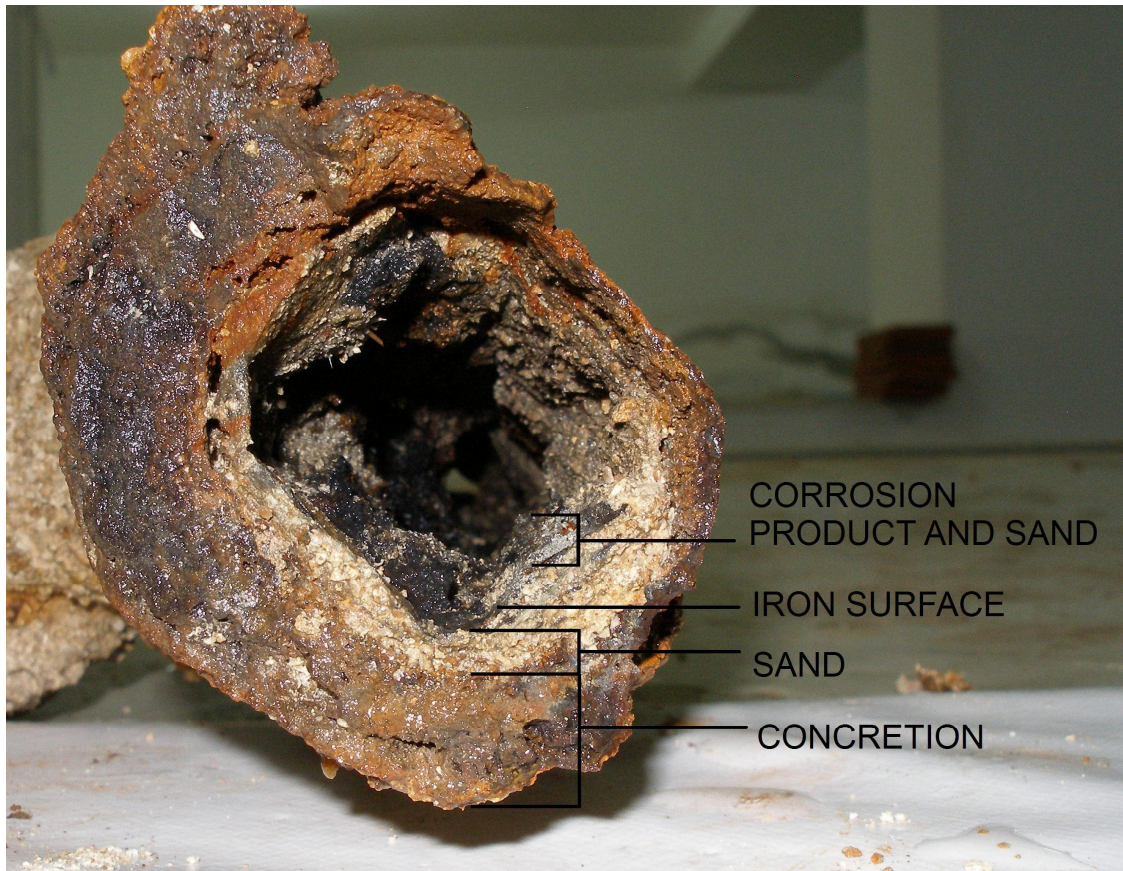


Fig. 2.12: Close-up of the break between ABX-4 and ABX-5. A thick wall of concretion surrounds a thinner layer of hardened sand, and the void as well is packed with sand and black dusty corrosion product, with the thin layer of iron clearly showing the central shank's octagonal shape.

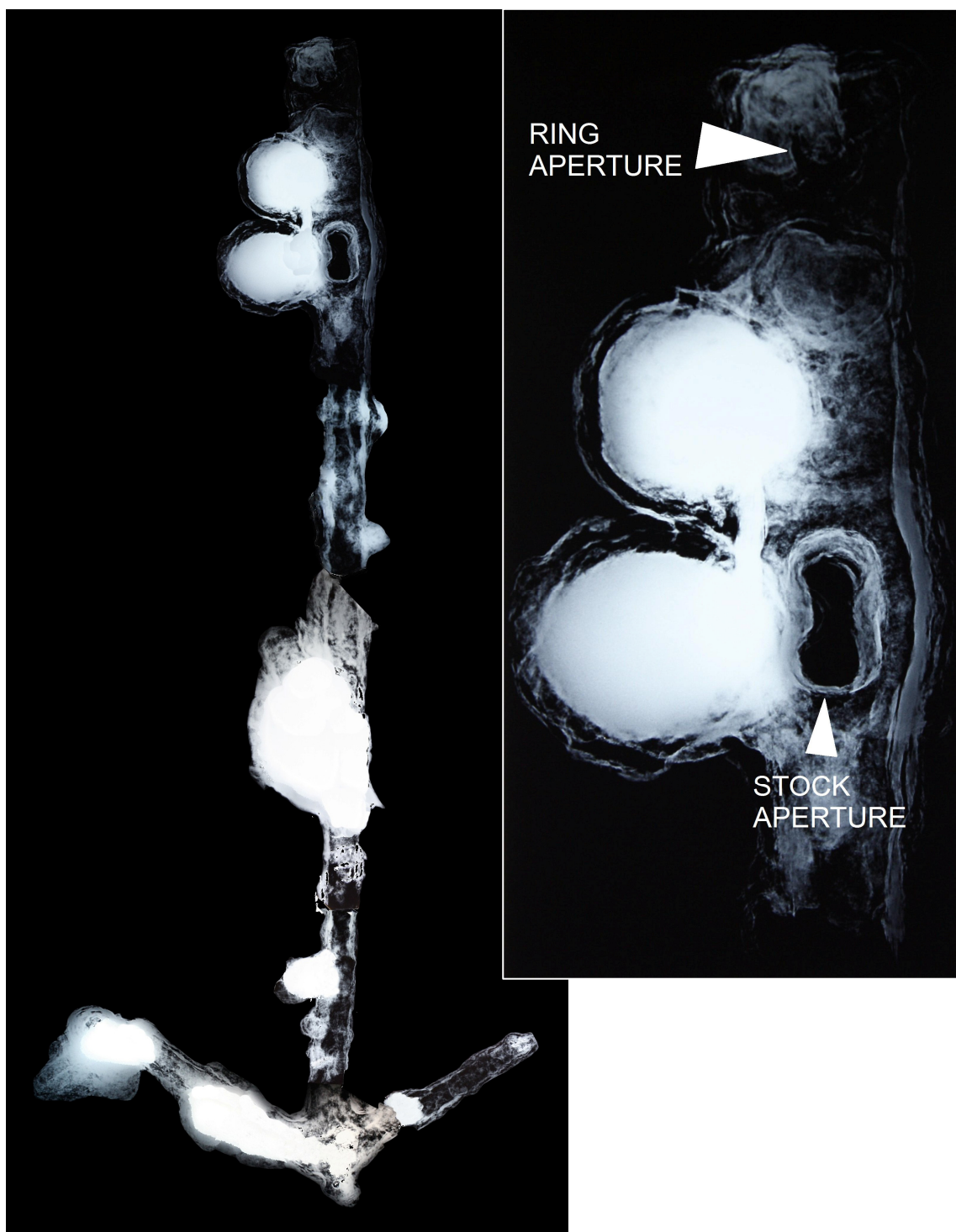


Fig. 2.13: X-rays of the individual sections stitched together (left), and x-ray of ABX-1 (right). Outline of object and apertures for ring and stock are clearly visible with dense concretion, impenetrable to radiography, appearing white.

### *The Anchor*

In 2008, casting began with ABX-2, the detached right arm. It was cleaned using the inner metal strip of a windshield wiper blade, an invaluable tool for emptying tiny cavities. Its thinness makes it useful for removing grit from the smallest crevices, its strength means it can be used to chip away hardened encrustation, and it can be bent to ensure that every angle within a concretion is free of sand and iron dust. Successive water flushing ensured the sand, which can obscure minute details and weaken the cast, was removed. After the sand was dislodged, water was again flushed through the section to check for unseen cracks that might cause epoxy to leak. Holes were plugged using plasticine, yet another important tool for the concretion casting process. When the leaks had stopped, the section was rinsed with acetone, eliminating large water droplets that can cause a pock-mark effect in the surface of the epoxy replica.

The arm was then placed with the opening upright in a box of sand, which served to stabilize the object until the epoxy hardened. Inevitably, epoxy leaks, and a bed of sandy material helps minimize the mess caused from a leaking cast. Small batches (less than 300 g) of Araldite Renlam M-1 epoxy were mixed one at a time to prevent waste. The best container for mixing is a simple wax paper cup, since the thermal reaction epoxy produces as it hardens has the ability to melt some plastics. The resin is first weighed, followed by the addition of the hardener, Araldite HY 956 hardener. The manufacturer, the Huntsman Corporation, suggests using 20% hardener for this particular epoxy resin, but test casts produced a final result that turned out too flexible and even sticky in

places, so the amount of hardener was increased to 25%. The necessity of increasing the percentage might be explained by the age of both the resin and the hardener, since it loses effectiveness over time. Perhaps a result of this increase, fumes noticeably arose from the cast as it reacted, which reaffirmed the fact that epoxy casting should be performed in well-ventilated areas. Every epoxy system is different, and it is strongly encouraged to follow the guidelines offered by the manufacturer to test the product. In addition, latex gloves should always be worn when handling epoxy, as the chemicals and the heat they produce can be caustic to skin.

When the process of replicating iron objects from their hollow concretions was developed in the 1960s, different materials were used. The first experiment was plaster, but it was found to be too friable. Later, both silicone rubber and polysulfide rubber were used with good results; however, shortly after replication, the silicone rubber tools began deteriorating. Polysulfide rubber gave a more realistic appearance for replicas and a longer shelf life.<sup>28</sup> However, 40 years after they were cast, the replicas of the 7<sup>th</sup>-century C.E. Yassıada tools began to sag and distort in their display cases within the Bodrum Museum of Underwater Archaeology. Conservators were able to mold the soft objects and recreate them using epoxy resin, which is now the standard in producing such objects, given its much harder texture and hopefully longer shelf life for the cured resin.

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<sup>28</sup> Katzev and van Doorninck 1966, 133-41.

For the Kızılburun anchor, epoxy was mixed using a tongue depressor until the mixture appeared uniform and had no textural swirls indicative of the separation of the resin and hardener. It was then slowly poured into the void, allowing time for it to settle into the cavities, as well as time for me to observe any new leaks. Subsequent batches were added as leaks were addressed, without necessarily allowing each batch to harden independently, until ABX-2 was entirely full of epoxy. Although it generally takes one or two hours before it sets, the cast was allowed to cure completely for 24 hours before additional handling.

The following day, preparations were undertaken to attach ABX-2 to ABX-3. ABX-3 was thoroughly cleaned, as described for ABX-2. Cleaning the interior void of the crown revealed the unmistakable presence of an aperture meant for another ring, and caution was taken to ensure it remained intact. It was decided to remove the wood and ceramic sherds from the underside of the left arm before attaching the sections together. These additional artifacts were chiseled free and assigned their own lot numbers.<sup>29</sup> During removal of the smaller fragment of wood at the midpoint of this arm, the tooth of the anchor was inadvertently separated from the remainder of the arm. I intended to remove the small fragment of wood and break the arm at its midpoint to ensure a thorough cleaning; however, the weight of the more substantial wood fragment near the tooth caused it to separate at the weakest point. Although unintentional, the removal of the tooth still guaranteed a thorough cleaning of the arm. Both fragments of wood and

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<sup>29</sup> Ceramic sherds were given Lot 283.03, and wood fragments were assigned Lot 283.04.

their surrounding concretion were too robust for manual removal, and a rotary saw was employed to saw off the fragments from the dense concretion. No concretion cavities or wood remains were harmed during this process.

Epoxy was poured into the lowermost portion of the crown, with only slight leakage occurring. Successive small batches were added until the aperture for the ring was covered in epoxy. It was only allowed to harden for half a day, and in the afternoon, work resumed on reattaching ABX-2 to ABX-3. Thankfully, the natural breaks joined very neatly, although there were larger holes along the breaks, where the most stress presumably occurred during degradation on the seabed. The two sections were held together while a thick layer of plasticine was applied around the entire circumference of the joint, bridging the missing pieces and creating a strong bond between the two previously disconnected segments. Epoxy was poured into the section until half of the ABX-2 break was covered with it. That was allowed to set until the following day when the two sections, now bridged with epoxy, were rotated so that ABX-2 was lying flat and additional epoxy could be poured into the remainder of the void without worrying about the two smaller sections shifting or cracking open. After letting it cure, the one large fragment (ABX-2 and ABX-3 combined) was rotated upright again. More epoxy was added until the level reached approximately 5.0 cm below the joint between ABX-3 and ABX-4. The now broken left arm remained empty temporarily.

Following the successful filling of the lowermost sections, it was decided that the cast's



rather thin shank would benefit from internal reinforcement.<sup>30</sup> Brass was determined to be the most suitable material to use for a reinforcement rod: its strength would protect the cast in years to come against accidents, it would be less susceptible to corrosion than iron, it was cheaper than a stainless steel rod, and it could be easily cut to size. The problem of how best to mount the rod was then addressed.



Fig. 2.14: Close-up of black plastic bracket mounted in the break between ABX-3 and ABX-4.

A plastic bracket was mounted in a small ball of plasticine and affixed to the solidified epoxy spanning the joint between ABX-3 and ABX-4 (Fig. 2.14). The bracket is a

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<sup>30</sup> Van Doorninck's disheartening description of one of the anchors from Serçe Limanı being inadvertently knocked over and shattering (2004, 192) led me to think about internal reinforcement. Additionally, the 7<sup>th</sup>-century C.E. anchors from Yassiada, although made of polysulfide rubber and therefore much softer were also reconstructed using an internal structure made of iron (van Doorninck 1982, Fig. 6-5).

hollow cylindrical piece of plastic, only slightly larger than the brass rod, with ridges along the outside, to keep it steady and in place. Epoxy was poured around the outside of the bracket, beginning with a small amount that was allowed to set up around the plasticine to prevent it from leaking into the empty inner hollow where the brass rod would be inserted. After allowing that to harden, it was deemed safe to add more epoxy until the epoxy level reached just below the break.



Fig. 2.15: ABX-2, 3, and 4 assembled.

When the bracket was sturdily mounted, ABX-4 was prepared for attachment. Since the section had two open ends, it was difficult to check for leaks prior to assembly; they

would have to be addressed as they appeared. Again, the break between ABX-3 and ABX-4 was completely bridged with plasticine (Fig. 2.15). Following the secure reconnection of the joint, the brass rod was gingerly threaded down the length of ABX-4 and inserted into its bracket, without touching the walls of the concretion (Fig. 2.16).



Fig. 2.16: ABX-2, 3, and 4 after mounting the brass reinforcement rod.



The plasticine ball holding the bracket in place retained enough elasticity so that it formed around the rod, and the rod did not shift after insertion. Batches of epoxy were poured into ABX-4, filling the cavity as well as the space between the bracket and the brass rod assembly, creating a permanent seal between the two. Meanwhile, the numerous leaks were plugged with more plasticine as quickly as they appeared. In retrospect, many leaks might have been avoided if the concretion had been consolidated by painting the outer surface with epoxy, Paraloid B72, or even a polyvinyl acetate emulsion.



Fig. 2.17: ABX-1 following its reconstruction. Arrows indicate the extensive amount of plasticine used to plug the copious leaks.

As the largest section, ABX-5 was the most problematic during casting. After thorough cleaning, the small cavity on the underside that was the end of the anchor stock was cast first, so that damage to the section could be avoided. After giving that time to set, I

decided that to minimize stress on the anchor during casting, the removal of the burdensome concretion would be beneficial. Since the concretion here was extremely dense, a rotary saw was employed yet again. Careful inspection of the concretion revealed that there were no additional voids or objects embedded in it, and, substantially lighter, ABX-5 could now be attached more easily. The piece was lowered carefully down the length of the brass rod and attached to ABX-4 with a thick layer of plasticine. Small balls of plasticine were also used to create spacers at the top of ABX-5 so that the brass rod would not rest against the inner walls of the void and perhaps protrude from the finished cast. Epoxy was poured in batches, with many leaks occurring, until it reached just below the break between ABX-5 and ABX-1a. The plasticine spacers were then removed before attaching the top pieces. ABX-1a was attached in a similar manner, with plasticine bridging the break and spacers used to keep the rod centered.

It was now time to turn attention to the most time-consuming pieces at the very top of the anchor (Fig. 2.17). Because of the tight inner spaces, it was necessary to break ABX-1 into two sections, right between the apertures for the stock and the ring. This was done by inscribing a line with a pneumatic chisel, or air scribe, around the desired breaking point just through the outer layers of concretion, followed by concentrated chiseling. Instead of breaking straight through, as was desired, the piece cracked in a diagonal manner very near the stock aperture, with some small fragments of concretion becoming dislodged. Although this did not happen exactly as planned, the break enabled thorough removal of the sediment. The inner walls throughout ABX-1 were determined

to be in excellent condition and very sturdy. Windshield wiper blades were especially effective in this area of the concretion, as their flexibility ensured that the tightest turns were cleared. Epoxy was first poured in the very top piece around the ring aperture and allowed to set. Then, the stock aperture was reattached with a plasticine bridge, while making sure that holes were plugged. The second half was then poured until it reached 2.0 cm away from the break. Excessive leaking ensued. The globular bleeds on the underside of the section contained numerous hairline fractures, previously unseen, which caused the epoxy to completely fill them. This made the piece substantially heavier than planned but did not adversely affect the cast. A second plastic bracket was inserted into the break between ABX-1 and ABX-1a, in exactly the manner previously described, to receive the other end of the brass rod.

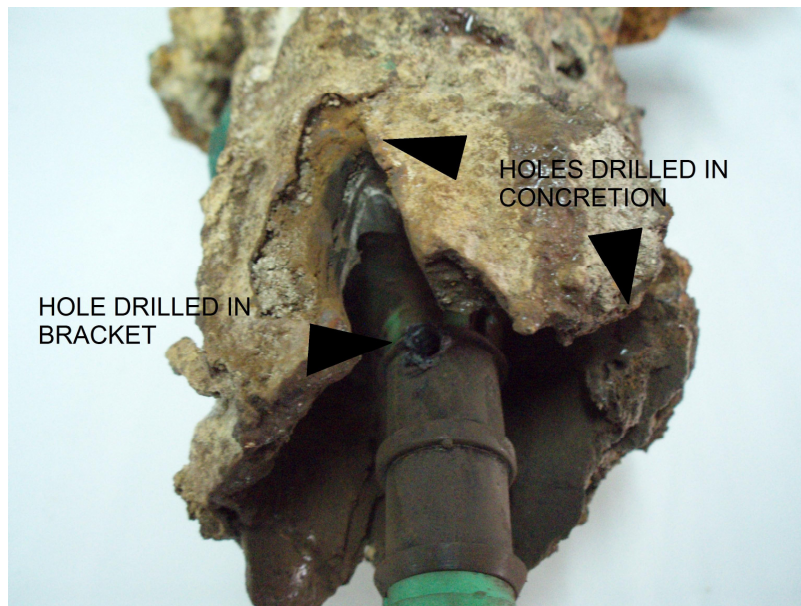


Fig. 2.18: Mounting bracket for reinforcement rod in ABX-1 with holes drilled in bracket and concretion to reduce air bubbles in cast.

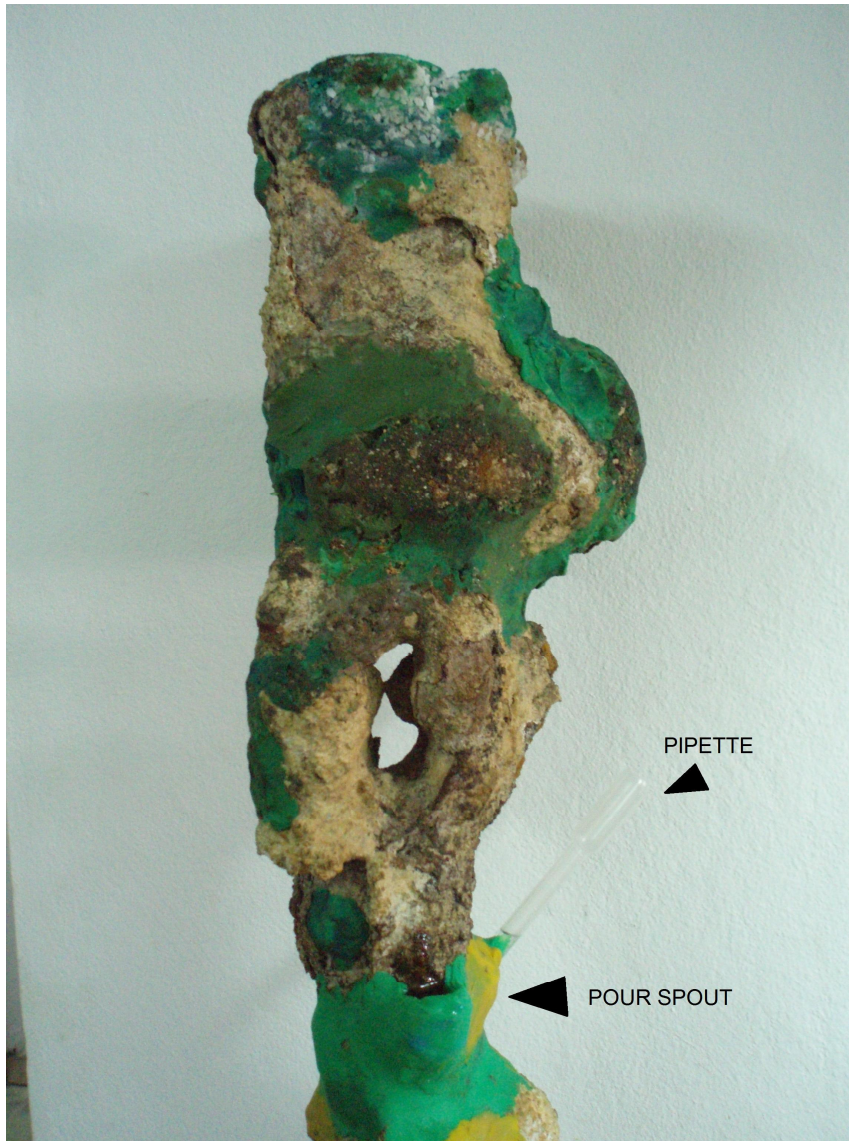


Fig. 2.19: Detail of ABX-1 with plastic pipette and pour spout.

Attaching the final piece meant having to work a liquid into upright spaces, and strategic planning was required to avoid air bubbles in the cast. A hole was drilled into the plastic bracket to allow epoxy to flow into the gap between the brass rod and bracket, eliminating the possibility of trapped air. Two additional holes were drilled in ABX-1

(Fig. 2.18), and the section was attached to the rest of the anchor. A plastic pipette was secured in one of the drilled holes so that air would be forced out by the rising epoxy. Around the second hole, a spout was manufactured using plasticine to facilitate the pouring of epoxy into the remaining cavity (Fig. 2.19). This was a very effective solution to the air bubble issue.

The last part to be cast was the tooth portion of ABX-3. Consolidation of the iron surfaces of the delicate tooth was attempted by injecting epoxy into the sand. By doing this, the iron remained in place, held steady by the encompassing cushion of now solidified sand. After pouring epoxy into the tooth, the rest of the ABX-3 arm was filled as much as possible. One hole was drilled into the tooth section, as described above for ABX-1, to allow for complete filling of the cavity. Only one hole was needed, since ABX-3 naturally lies on its side, unlike ABX-1 which was required to stand upright. Air bubbles within the cast did not prove to be an issue. The tooth was reattached with a bridge of plasticine, and a spout was formed to enable pouring of epoxy into the void (Fig. 2.20). The anchor, now in one piece, was allowed to sit for 24 hours before air scribing commenced (Fig. 2.21).





Fig. 2.20: The pour spout designed for ABX-3.



Fig. 2.21: The fully reconstructed and cast iron anchor concretion.

### *The Anchor Stock*

Preparation of the pieces comprising the anchor stock then began. Serving as the base for the cast, ABX-8 was cleaned first. During cleaning it was apparent that the metal surface was incredibly delicate, and most of it came out while removing the sand, and trying to replace the fragments proved unfruitful. A tremendous amount of epoxy was needed for the piece, and it was feared that none of the original surface remained in the very end of the stock.

The large concretion bleed attached to the underside of ABX-7 was removed using a hammer and chisel and immediately placed into wet storage to preserve the wooden plank details. After ABX-8 was allowed to harden, ABX-7 was attached to it using a plasticine bridge. Epoxy was poured until reaching a distance of 5.0 cm from the ABX-6 break. ABX-6 was attached to the rest of the concretion with plasticine and completely filled with epoxy. It was decided that due to the curvature of the piece, a brass rod may be more problematic to insert, therefore the stock received no internal reinforcement. The three pieces comprising the stock joined very snugly together, and the breaks between them saw very little leaking during casting, unlike the anchor. After separation of the small section of the stock from ABX-5 during mechanical cleaning, it was able to be attached to the rest of the stock, and casting was completed without problem (Fig. 2.22). A hole spanning the break between this piece and ABX-6 was used as the final pouring spot to finish the stock.



Fig. 2.22: The fully reconstructed and cast iron anchor stock concretion.



### *Mechanical Cleaning of the Anchor and Stock*

Mechanical cleaning was begun on the anchor in a place determined to be the most promising in terms of finding the surface of the cast quickly and easily. Since it was known that the very end of the stock was underlying the anchor shank, this seemed a natural place to quickly find the surface of the anchor. Observations during casting allowed an educated guess as to where to find the surface of the shank amid the concretion. Quickly, the interface where the stock abutted the anchor became apparent, and air scribing continued until the two could be separated. While there was a good original surface on much of ABX-5, spots in which sand had obstructed the cast became visible in due course.



Fig. 2.23: Preserved cross-section of possible rope within the anchor concretion.

A small round cross-section of organic material was discovered within the concretion surrounding the shank. Coral of similar description is commonly found in iron encrustation, but the fibrous center made it appear that the coral had formed around something else. The remains were fragile and iron-impregnated and disintegrated upon attempted removal, due to the vibrations of the air scribe. Its appearance gave the impression that this round fragment may have been rope associated with the anchor. Its preserved diameter was 2.1 cm (Fig. 2.23). A small fragment of rope was discovered within an anchor concretion from the 11<sup>th</sup>-century C.E. Serçe Limanı wreck, with a diameter of 1.5 cm,<sup>31</sup> but rope described from other shipwrecks was more easily identified and unencumbered by concretion.

For comparison, two lines were discovered still attached to the anchor associated with the 5<sup>th</sup>-century B.C.E. Ma'agan Michael vessel in Israel, with a diameter of 2.0 cm for the rope attached to the crown and 4.0 cm for the line looped through a slot at the head of the shank.<sup>32</sup> Similarly, cordage of varying sizes was found on the 3<sup>rd</sup>-century B.C.E. Marsala Punic shipwreck, and one fragment with a 5.5 cm diameter was associated with the anchor.<sup>33</sup> Two ancient wooden anchors found at Ein Gedi on the Dead Sea still had ropes attached: three lines attached to a one-armed anchor, all with a diameter of roughly 2.0 cm, and two ropes associated with the wooden Hellenistic anchor, with

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<sup>31</sup> van Doorninck 2004, 206.

<sup>32</sup> Rosloff 1991, 223 and Charlton 1996, 62-6.

<sup>33</sup> Frost 1981, 93-7 and Charlton 1996, 66-7.

diameters of 4.0 cm and 1.6 cm for the upper and lower ropes respectively.<sup>34</sup> Taking these measurements into consideration, it may be that the rope found within the Kızılburun anchor concretion was meant for the trip-line, the line attached to the crown of the anchor to enable easier removal from the seabed. However, without any additional rope remains, and given its central location along the anchor's shank, it is impossible to say definitively which line it represents.

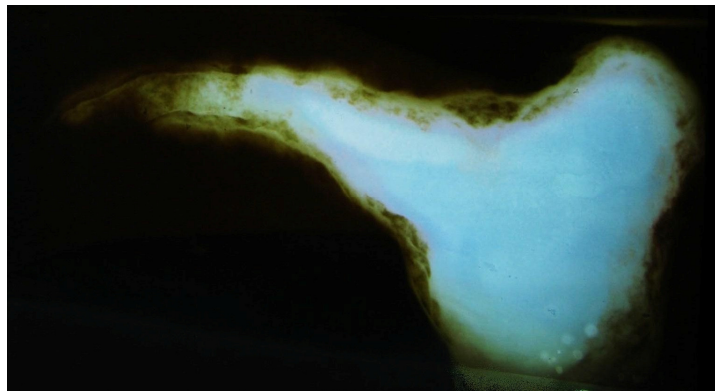


Fig. 2.24: X-ray of the anchor's ring (Lot 311), taken with the x-ray machine in the Nixon Griffis Laboratory.

After removal of the concretion began at ABX-5, it was clear that the anchor had a non-regular octagonal shape throughout its midsection. The four large faces were clearly defined, and four small bevels between them could be identified. In the fall of 2009, air scribing as well as the grinding down of large epoxy leaks was completed. The anchor was then given a facelift in some areas using epoxy putty and paint to mimic the look of the original surface in those places where it did not survive. Mechanical cleaning of the

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<sup>34</sup> Hadas et al. 2005, 303-4.

stock was begun in the fall of 2009 as well, when it became apparent that the metallic surface of the stock was in a significantly better state than that of the anchor, probably due to the fact that the stock was completely buried in the sandy seabed and therefore less susceptible to damaging currents at Kızılburun.

### *The Anchor's Ring*

All that was preserved of the elements for securing cables to the anchor was a portion of a ring (**AR 1**) that would have been attached at the head of the shank. Although there was an aperture at the crown as well, the crown ring did not survive. Following casting, the bulbous object found lying downslope of the anchor concretion (Lot 311) was revealed to be a fragment of the upper ring. In its x-ray (Fig. 2.24), the outline of the ring is seen, as well as its curvature. Despite not surviving in its entirety, the diameter can be estimated at 14.0 cm and the thickness at 1.0 cm, although it is impossible to remark on its manufacture. The ring survived in two cast sections, but the second of the two is in such a poor state that no relevant measurements could be deduced (Fig. 2.25).



Fig. 2.25: **AR 1**, the anchor's ring after excavation and following casting.



Two Hellenistic anchors from Ashkelon, Israel were found with their upper rings still attached. In this case, the rings were elliptical in shape, the largest measuring 23.0 cm by 34.0 cm and made from a 2.0 cm-thick rod. The smallest measures 17.0 cm by 12.5 cm and was made from a rod 1.5 cm thick. Since only a portion of the anchor ring from Kızılburun survives, its shape cannot be determined: it may have been round or more probably elliptical. Two one-armed anchors were also discovered at Ashkelon, only one of which was recovered. The surviving portion of its ring, presumably round, has an estimated diameter of 11.0 cm.<sup>35</sup> Another ring was found intact at Isla Pedrosa, Spain and is dated to the 2<sup>nd</sup> century B.C.E., but no measurements were reported.<sup>36</sup>

## INTERPRETATION

The Kızılburun iron anchor is an unusual find in that both the anchor and its stock were found intact (Fig. 2.26). The anchor is 1.64 m long with an arm span of 69.2 cm. A rough estimate of its original weight including the stock is 38.5 kg, calculated using the density of iron and the volumetric measure of the anchor in cubic centimeters.

Calculations for the anchors from the 7<sup>th</sup>-century C.E. ship from Yassıada were performed in the same manner, however, unoxidized portions yielded a density for the specific iron used in their manufacture<sup>37</sup> and with no such iron remaining from **AN 1**, an accepted density for iron (7.8 g/cm<sup>3</sup>) was used to calculate its weight.<sup>38</sup>

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<sup>35</sup> Galili et al. 2010b, 126-9, Figs. 4, 7-8.

<sup>36</sup> Foerster 1969, 22-3.

<sup>37</sup> van Doorninck 1982, 131-4.

<sup>38</sup> Another study of Byzantine anchors from Tantura Lagoon in Israel conducted by Eliyahu et al. (2011, 238-40) used 7.8 g/cm<sup>3</sup> in determining weights for anchors with missing sections.



Fig. 2.26: AN 1 (left) and ST 1 (right).

There are several details that can be deduced from the anchor's position on the seabed. The fact that it was lying on its own stock denotes that the anchor was stowed and not actually in use at the time of the ship's sinking. The orientation of the nails found beneath the stock reveals that it was likely stowed in the hold of the ship and was lying against part of the wooden structure. The presence of clenched nail tips within the anchor's concretion indicates that the anchor was resting directly against a frame within the hold. During construction of a wooden hull, nails are driven through planking and clenched over a framing timber; the clenched tips abutting the stock in this case eliminate any space necessary for a layer of internal planks. Had the nail heads and not the tips been concreted to the underside of the anchor, this might have suggested a location on deck, or the presence of ceiling planking within the hold. The iron anchor from the Grand Rouveau shipwreck in France also contained traces of wooden planking and mortises within its concretion, suggesting that it too was not the primary anchor and was stowed at the time of sinking<sup>39</sup>

**AN 1** was situated parallel to the outer planking as evidenced by the fact that an impression of two adjoining planks was preserved within the iron concretion, in which the direction of the wood grain can be seen. The crown pointed upslope, not quite on the same axis as the keel. The excavation only recently came to a close, and interpretation of the wreck has determined that the upslope areas probably represent the bow of the

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<sup>39</sup> Liou and Corsi-Sciallano 1985, 65.

ship.<sup>40</sup> It is difficult to give a precise location for the stowed anchor within the hold of the vessel, with so few hull remains; however, it appears that the anchor was near midships on the starboard side.

The overall shape is an affirmation of its age, being distinctly Hellenistic, with its V-shaped arms<sup>41</sup> and a shank with a cross-section that changes shape from rectangular at the lowermost section to octagonal throughout the middle and rectangular again at the top, characteristics visible in the Bodrum bronze anchor, two iron anchors found at Ashkelon in Israel,<sup>42</sup> the iron anchor from the 1<sup>st</sup>-century B.C.E. shipwreck at Capo Testa, Italy<sup>43</sup> and the lower portion of an anchor from the Hellenistic shipwreck at La Ciotat, France.<sup>44</sup> The Hellenistic V-shape can be seen in a 2<sup>nd</sup>-century B.C.E. anchor from Isla Pedrosa, Spain,<sup>45</sup> in at least one of the anchors from the Punta Scaletta shipwreck (Italy),<sup>46</sup> the iron anchor from the ca. 100 B.C.E shipwreck at Cap Taillat (France),<sup>47</sup> and in the iron anchor from the 1<sup>st</sup>-century C.E. wreck at Grand Rouveau (France),<sup>48</sup> although the respective authors do not specify an octagonal section through the shank. Specifically studying the break between ABX-3 and 4, it is doubtful that **AN 1** had a wood casing, like the anchor found in Italy's Lake Nemi.<sup>49</sup> The concretion

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<sup>40</sup> Littlefield 2012.

<sup>41</sup> Kapitän 1984, 42; Haldane 1990, 23.

<sup>42</sup> Galili et al. 2010b, 126.

<sup>43</sup> Gandolfi 1986, 81 and Fig. 4.

<sup>44</sup> Benoit 1958, 26, Fig. 29.

<sup>45</sup> Foerster 1969, 23.

<sup>46</sup> Lamboglia 1964, 253-7.

<sup>47</sup> Joncheray 1987, 141-2.

<sup>48</sup> Liou and Corsi-Sciallano 1985, 65 and Fig. 52.

<sup>49</sup> Speziale 1931, 314 Fig. 1.

would likely be much thicker in such case, encasing the wood as well. There was also no wood within the concretion, and it should have been apparent, since iron corrosion preserves wood within its concretion matrix, as seen in other concretions from Kızılburun. It can be said without doubt that **AN 1** consisted only of iron.



Fig. 2.27: Close up of Haifa anchor with notch in top of stock aperture (photo by author).

The stock aperture revealed an interesting feature during manual cleaning, and after inspecting the smaller of the two iron anchors from Ashkelon, now in the Haifa Museum, it seems that this trait may have been common of ancient iron anchors. On both the small two-armed anchor from Ashkelon (Fig. 2.27) and the Kızılburun anchor

(Fig. 2.28), there is a notch in the top of the rectangular slot for the stock, the function of which is unknown at this time. It is doubtful that it played a part in holding the stock in place, as the pin attached to the stock should have served that function alone, but the notch could have been used to receive a shim to reinforce the fitting of the stock to the anchor.



Fig. 2.28: Close up of AN 1 showing notch.

It was hoped that this study of the Kızılburun anchor would provide the same insight into the manufacture of Hellenistic iron anchors as van Doorninck's study did in shedding light on the production of Byzantine Y-shaped anchors.<sup>50</sup> The concretions of the Serçe Limanı anchors, being intact, had protected the internal cavities from damage caused by currents and sand activities on the seabed. Because it was broken, the Kızılburun anchor concretion suffered from centuries of natural forces taking their toll on the delicate inner

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<sup>50</sup> van Doorninck 2004, 221-4.

cavities. Many original surfaces were no longer attached to the concretion, and much of the black corrosion powder had been flushed out and replaced by coarse sand.

Unfortunately, because of the weakening of the internal portions of the mold, it is impossible to comment on the presence of welding seams or speculate about the process of this anchor's manufacture.

As previously mentioned, the large object lying perpendicular to the anchor shank was its own stock. Kapitän goes on to say that this type was beneficial for purposes of easy stowage but limited the size and thus the weight of the anchor, since it required more physical handling.<sup>51</sup> The stock has a pronounced curvature, which mirrors the large bronze anchor on display in the Bodrum Museum of Underwater Archaeology as well as the two iron anchors and stocks found on the Ashkelon Hellenistic shipwreck off the coast of Israel.<sup>52</sup> The stock measures 130.9 cm in length and varies in width from 5.5 – 6.5 cm.

Although the x-rays showed questionable presence of a hole in which a removable pin was inserted in order to affix the stock, an impression of this hole can be seen in the finished cast. Ideally, such openings become concreted just as the apertures for the rings in the anchor did, preserving original dimensions; in this case the concreted remains of the hole had been damaged and did not survive. However, there is a round epoxy

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<sup>51</sup> Kapitän 1984, 39.

<sup>52</sup> Galili et al. 2010b, 127 Fig. 3.

indentation in the metal surface on the flat side of the stock, with a fairly well-defined diameter of 1.1 cm (Fig. 2.29). As expected, however, ABX-8 did not retain any original surface and will need substantial reconstruction.



Fig. 2.29: Evidence of pin-hole in stock in the form of round epoxy leak.

The small protrusion visible within the heavy concretion of ABX-8 is a still-metallic iron bar, approximately 21.5 cm in length, 5.5 cm in width, and 1.0 cm in thickness. Just below this iron bar was a thin remnant of wood, only 0.3 cm thick. It does not appear to be planking because of its thinness, and its purpose is currently unclear (Fig. 2.30). The conservation process for the iron bar as well as its interpretation is discussed in the following chapter along with the other small objects excavated at Kızılburun.





Fig. 2.30: Detail of iron bar and wood remains concreted to ABX-8.

The bronze anchor in Bodrum has an additional ring on its stock, which facilitated the lifting of the massive anchor from the seabed using an additional line. There is no evidence for a ring attached to the Kızılburun stock, where it should have occurred: at the end concreted to the underside of the anchor shank. The other end, ABX-8, would have had to pass through the anchor shank for the stock to be affixed properly, thus making a ring at that end an impossibility. For additional comparison, the two Hellenistic anchors now in the Haifa Museum in Israel have similar constructions: two rings on the anchors, at the head of the shank and at the crown, and none on the stocks.<sup>53</sup> Based on this evidence, a ring on the stock was not always a necessity when handling

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<sup>53</sup> Galili et al. 2010b, 126-7.

smaller anchors that were lighter in weight.



Fig. 2.31: Detail of step.

During removal of the concretion from the stock in 2009, it became apparent that the step designed to hold the stock in place had survived. The lines of the step are visible in the x-ray, but since only one angle was shot, the extent of its preservation was uncertain, although eventually it was found to be well-preserved (Fig. 2.31). In situ, the stock was situated with the step facing downward. There is also a noticeable twist to the stock: it is not simply straight and flat, but after moving past the step, one end is twisted, which may have been either a result of manufacture or a violent shock during previous use.



Fig. 2.32: Position of welds visible on underside of anchor stock.



Fig. 2.33: Detail of weld nearest step.

The present outermost layer reflecting the original metal surface of the stock remains in remarkable condition, thus making it possible to study markings and clues to its manufacture. Fortunately, three welds are visible (Fig. 2.32), which suggests that the



stock was made of at least three pieces of iron. The telling characteristic for a weld occurs in the form of a sudden change of texture or elevation in the surface where two pieces of iron were forged together. The most obvious of the welds occurs near the step, at the ABX-5 end. It has a pronounced ridge on the flat surface as well as on the underside (Fig. 2.33). The second is found on the other side of the step, and the last occurs right at the juncture of ABX-7 and ABX-8.

### THE WOODEN ANCHORS

Other anchors from the Kızılburun ship exist in the form of six individual lead components originally attached to wooden anchors, as well as an iron anchor tooth which would have reinforced the arm of a wooden anchor. The presence of three lead reinforcement collars suggests that there were three wooden composite anchors in addition to the iron anchor. An additional damaged collar was probably not in use as an anchor during the voyage of the column drums.

Like iron anchors, Hellenistic wooden anchors have distinct definable components. The shank and arms were made of wood, but the addition of a lead collar provided reinforcement where the arms and shank met. The stock, also made of lead, had a central tenon which passed through an aperture in the upper part of the anchor's shank. Stocks vary in design, and a second lead stock at Kızılburun is a removable type with features mimicking the stock found in association with the iron anchor and therefore functioning in the same manner. The arms ended in a point and were occasionally

sheathed in bronze or iron teeth (Fig. 2.34).<sup>54</sup>

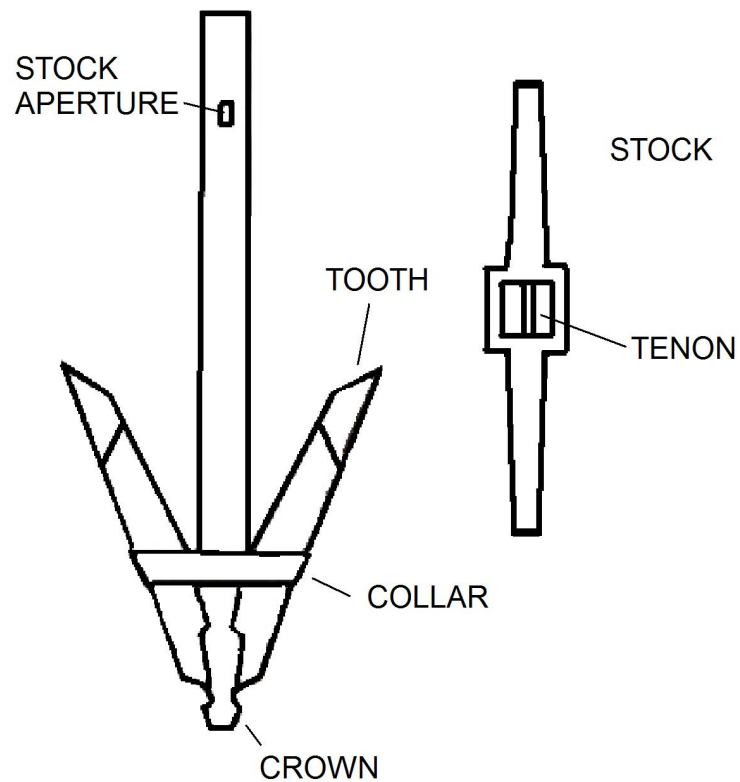


Fig. 2.34: Components of an ancient wooden anchor (left) and its stock (right) (drawing by author).

### *Iron Anchor Tooth*

Because the iron concretions are the focus of this thesis, the iron anchor tooth was addressed first. A large hollow cone-shaped concretion (**AT 1**) was found upslope of the drums. The x-ray for this particular object revealed that the portion surrounding the hollow contained a very thin cavity, and it terminated in a more blunt shape (Fig. 2.35). An attempt was made to break open the more robust end using a hammer and chisel;

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<sup>54</sup> Terminology from Haldane 1990.

however, the thin upper portion began to shatter with every blow of the hammer. An air scribe was used to thin the concretion in a line around the blunt end without actually piercing the cavity, followed by the use of a fine pointed chisel to cleanly break the concretion. After finally separating, the cavity within the more heavily concreted section could be identified as the terminal end of an anchor tooth, commonly used to reinforce and protect the extremities of wooden anchors. The thin upper portion is what remains of the component that sheathed the arm. Fragments of wood were preserved in the concretion thus confirming that the iron tooth reinforced the arm of a wooden anchor.



Fig. 2.35: X-ray of **AT 1** (left) and its concretion (right).

Casting the object was challenging, as the thinnest areas of the concretion housed what can best be described as a sheet of iron, therefore the cavity surviving in this case was very thin. The broken extremity was cast first and then reattached to the upper portion of the concretion using plasticine. The fragments of the thinner concretion, created while separating the bottom, were pieced back together and held in place with plasticine

bridges. Epoxy was drizzled down the iron sheet until it seemed that the larger cavities had been filled. The encrustation surrounding the end of the tooth was removed easily and revealed a well-preserved epoxy replica of the once iron object (Fig. 2.36).



Fig. 2.36: Two views of **AT 1** following removal of majority of encrustation.

It was undesirable at this time to remove all of the concretion surrounding the upper sheeting, as encased in it were fragments of wood and it was best to leave them in place until they can be further analyzed. The preserved maximum length from the point of the

tooth to the end of the preserved cavity of the iron sheath is 28.0 cm. There are two grooves, running down the length of the tooth toward the cone, at a depth of 0.9 cm from the surface of the point. This design detail calls into doubt the simplicity of hammering a sheet of iron into a cone shape around the wooden arm. The preserved span of the cone is 9.0 cm, which reflects the width of the wooden arm once seated within this protective sheath.

Few examples of anchor teeth have been found, although it is not an uncommon topic among ancient writers. Pindar mentions a bronze-toothed anchor being hoisted alongside a ship in his 5<sup>th</sup>-century B.C.E. *Pythian Odes*.<sup>55</sup> Three bronze anchor teeth were found among the wreckage of the 4<sup>th</sup>-century B.C.E. shipwreck at Porticello, Italy. The author describes each of them as a hollow cone shaped from a bronze sheet and secured to the arms with tacks, estimated by the presence of tack holes.<sup>56</sup> There is no evidence for how the anchor tooth from Kızılburun might have been attached to the arm, since no holes can be detected, and no associated tacks were found.

Another early archaeological example for reinforcement teeth was found on the 5<sup>th</sup>-century B.C.E. Ma'agan Michael shipwreck excavated off the coast of Israel. In this case, the one-armed anchor had a copper tooth, which had corroded away, attached to the arm using three iron fasteners.<sup>57</sup> One iron tooth, rectangular in section, was identified

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<sup>55</sup> Pind. *Pyth.* 4.40.

<sup>56</sup> Eiseman 1979, 33-5 and Eiseman and Ridgway 1987, 19-21.

<sup>57</sup> Rosloff 1991, 223.



from the 3<sup>rd</sup>-century B.C.E. shipwreck at Tour-Fondue in France. It was likely attached using bolts or rivets driven through the arm and central tenon of the tooth.<sup>58</sup> Another was found using a metal detector in association with the one-armed anchor of the 3<sup>rd</sup>-century B.C.E shipwreck off Kyrenia, Cyprus.<sup>59</sup> One wooden anchor found at Ein Gedi near the Dead Sea and dating to the Hellenistic period had distinct rust staining at the end of the arms, which the authors determined indicated the previous presence of iron teeth.<sup>60</sup> Two were excavated from the Chrétienne C shipwreck in France dating to the 2<sup>nd</sup> century B.C.E.,<sup>61</sup> and yet another pair was discovered still attached to the wooden anchor from Lake Nemi, dating to the 1<sup>st</sup> century C.E.<sup>62</sup> Referring to them as “iron peaks” at the ends of wooden flukes, Speziale describes their attachment to the arm using iron bars wrapped around the four surfaces, reinforcing the attachment point.<sup>63</sup>

It is unknown how frequently metal teeth were used for reinforcement, since relatively few examples have been noted, compared to the number of wooden anchors found. According to Kapitän, inasmuch as iron was subject to corrosion during the life of the anchor and well before deposition may account for the lack of archaeological examples.<sup>64</sup> Haldane opines that anchor teeth may have been used in abundance, given that they are mentioned by more than one ancient writer, using more than one word to

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<sup>58</sup> Joncheray 1989, 141-3.

<sup>59</sup> van Duivenvoorde 2012, 398, 404-6, and Figs. 6-8; Green et al. 1967.

<sup>60</sup> Hadas et al. 2005, 303.

<sup>61</sup> Joncheray 1975a, 104.

<sup>62</sup> Speziale 1931, 312.

<sup>63</sup> Speziale 1931, 319.

<sup>64</sup> Kapitän 1984, 42.

describe them.<sup>65</sup> Livy uses *dente* which Sage translates into “fluke,” but a literal English translation is “tooth.”<sup>66</sup> Babbitt also translates Plutarch's wordage into fluke, but the literal translation of the ancient Greek, is that the *ὄνυχα* or “claw” had been separated from the anchor.<sup>67</sup>

### *Lead Stocks and Collars*

Diodorus Siculus writes that greedier merchants, attempting to load more silver cargo into their ships, hammered the lead off their anchors and replaced them with similar components made of silver.<sup>68</sup> While anchors with silver components would be an interesting find indeed, Diodorus at least gives us insight into a common practice: the use of lead on ancient anchors. Four lead reinforcement pieces, known as collars, were found among the wreckage, the three largest of which (Lots 368, 369 and 887, weighing 11.94 kg, 10.94 kg and 16.90 kg respectively) have a positive connection to the ship's last voyage (Fig. 2.37). The fourth smallest collar (Lot 1220) was excavated from beneath Drum 1, once the drum was relocated off site. This collar, weighing only 3.48 kg, was found with no associated stock, and it had been distorted by the weight of the drum (Fig. 2.38). While the fact that its stock is missing cannot wholly discount it being a part of the ship's equipment, the collar's resting position beneath Drum 1 calls into doubt its use as an anchor during the final voyage of the Kızılburun Column Wreck.

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<sup>65</sup> Haldane 1986, 166.

<sup>66</sup> Livy 37.30.9-10.

<sup>67</sup> Plut. *Mor. De mul. vir.*, 247e.

<sup>68</sup> Diod. Sic. 5.35.4.



Fig. 2.37: 3 lead anchor collars (Lots 887, 369 and 368 from top to bottom) found on the wreck site (photos by H. Brown and J. Levin).



Fig. 2.38: Lot 1220, the anchor collar found beneath Drum 1 (photo by J. Littlefield).

The two lead anchor stocks are of different types. The first stock (Lot 825), weighing 105.72 kg, was found near two lead anchor collars in area 18, and it is a type commonly found in the Western Mediterranean (Fig. 2.39).<sup>69</sup> The heavy stock enabled the teeth of the anchor to better grip the sea floor. This lead stock is a permanently fixed type, in that once it was affixed to the anchor, the stock could not be removed without damaging the anchor itself, since it has a central lead tenon which pierced the wooden anchor shank. Haldane refers to this type as a Type III-B stationary lead stock, the use of which occurred between the 3<sup>rd</sup> century B.C.E. and the 1<sup>st</sup> century C.E.<sup>70</sup>



Fig. 2.39: Lot 825, the larger of the two lead anchor stocks (photo by H. Brown).

The second stock (Lot 1334), weighing 34.32 kg, exemplifies a transitional design and an improvement in anchor technology (Fig. 2.40). It was located upslope and approximately 20 m northeast of the main wreck site, but this fact does not negate its inclusion in the Kızılburun assemblage. Haldane characterizes stocks of this design as a

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<sup>69</sup> See Parker 1992 for the most complete catalog of anchors found in the Mediterranean.

<sup>70</sup> Haldane 1984, 7-8, Ill. 1.

Type IV-B removable lead stock with step, which laid the groundwork for the technological transition to iron anchors with removable stocks. He also characterizes this type as being predominately Eastern Mediterranean.<sup>71</sup> Whereas the stationary stock was permanently affixed to the wooden anchor during manufacture, a removable stock was produced separately and attached only when in use by being slotted through a rectangular cutout in the anchor's shank and being held in place with a pin. An anchor of this design was advantageous in being more easily stowed and in essence collapsible as it can be stored flat on the deck. It also has its limitations, because inserting the stock before use requires more handling and this in effect would limit the overall weight of the anchor.<sup>72</sup> This could account for the great difference in the weights of the two recovered stocks.



Fig. 2.40: Lot 1334, the heavily concreted removable lead stock (photo by J. Littlefield).

## DISCUSSION

The significance of anchors to the ship carrying them was well-expressed in more than

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<sup>71</sup> Haldane 1990, 21-2; see also Kapitän 1984.

<sup>72</sup> Kapitän 1984, 39.

one ancient tale. Beneath the fabric of each well-told story lies the same truth: the anchor was as much an important piece of equipment as it was a common symbol of stability and faith, as it remains to this day. The first mention of an iron anchor occurs in the 5<sup>th</sup>-century B.C.E. writings of Herodotus;<sup>73</sup> however, it appears that the writer uses the word “anchor” figuratively as a description for a shield device. The custom of carrying multiple anchors was alluded to in ancient allegories, highlighting that it was common practice. Plutarch compares a city guided by two consuls to a ship riding with two anchors that is less affected by a surge.<sup>74</sup> Additionally, Epictetus is credited with writing, “Neither should a ship rely on one small anchor, nor should life rest on a single hope.”<sup>75</sup>

Several historical accounts recall ships with multiple anchors as well. Pindar advises in his *Olympian Odes*, “On a stormy night, it is good to have two anchors to throw down from a swift ship.”<sup>76</sup> In Acts 27, the anchors on St. Paul’s ship are cast into the sea to lighten the ship so that it can be purposefully beached.<sup>77</sup> In a passage in Dio Cassius’s *Roman History*, he refers to anchor cables being cut by Caesar’s men in an attempt to quickly cast off and fight an enemy.<sup>78</sup> Athenaeus, after the earlier but lost writings of Moschion, writes soon after 200 C.E. of Hieron’s ship *Syracusia*, built in the 3<sup>rd</sup> century

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<sup>73</sup> Hdt. 9.74.1.

<sup>74</sup> Plut. *Vit. Sol.* 19.

<sup>75</sup> Epictetus, Fragment 84.

<sup>76</sup> Pind. *Ol.* 6.

<sup>77</sup> Acts 27.39-44.

<sup>78</sup> Dio Cass. 48.4.6.

B.C.E., carrying four wooden and eight iron anchors.<sup>79</sup> To possess more than one anchor is a practicality that ancient sailors recognized when sailing unpredictable seas.

Physical examples of iron anchors remain rare until the 2<sup>nd</sup> century B.C.E., and even then, there are few wrecked ships which carried iron anchors. The iron anchor at Kızılburun is one of many found in the Mediterranean, although most have not been restored or published in detail, and additionally, there always exists a problem of finding them within a datable context, since anchors were often abandoned when too entangled to be raised from the seabed.<sup>80</sup> Another issue with dating anchors is that they are often found at a distance from a shipwreck, due to the act of casting an anchor in an attempt at saving the ship, so clearly establishing an association with a given wreck site can be challenging.

While the Kızılburun iron anchor in itself is unquestionably interesting, its occurrence alongside wooden anchors illuminates an even more interesting trend. The time-frame during which iron and wooden anchors occur together in an archaeological context spans approximately 600 years. The earliest shipwreck found with both types is the Secca di Capistello wreck in Italy dating to ca. 300 B.C.E. (established by the ceramic cargo), with one iron anchor complete with stock and at least two wooden, determined by the presence of three lead bars which were the cores for wooden stocks. The iron anchor in

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<sup>79</sup> Ath. 5.208.

<sup>80</sup> Kapitän 1984, 33.



that case appears to have been cast at the time of sinking, given its distance of 5 m from the wreck site.<sup>81</sup> The latest ship with both types dates to the 4<sup>th</sup> century C.E. The shipwreck at Le Scole, Italy (dated by the ceramics) again had one iron anchor and two lead stocks indicating two wooden anchors.<sup>82</sup> While most of the shipwrecks found with both types had only one iron anchor, five ships were found carrying multiple.<sup>83</sup> That this remains rare until the Late Roman period might be attributed to various factors: the cost of iron, the preference toward wooden anchors, or concern about the susceptibility of iron to corrosion.

The iron anchor from Kızılburun in itself is a remarkable find especially when paired with its own anchor stock within a datable context. However, the presence of other anchor types alongside has many implications for the development of shipbuilding and seafaring technology. Anchors evolved through the ages, while shapes, sizes, and material adapted to fit both necessity and changes in resources. The reasons driving the shift from wooden anchors to iron are unknown and might include any number of factors, from the expense of procuring lead to the advancements in ironworking,<sup>84</sup> but the concurrent use of the two types for centuries before wooden anchors completely disappeared suggests that there were reasons for sailing with both types. Campbell

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<sup>81</sup> Frey et al. 1978, 295-6. Preliminary measurements were taken of the anchor (2.0 m long x 7.0 cm wide) and its stock (1.3 m long x 5.0 cm wide) but no other details were noted, other than the distinctive V-shape of the arms, before the two were re-deposited on the seabed.

<sup>82</sup> Rendini 1982, 50-1.

<sup>83</sup> Punta Scaletta, Italy, 3 iron, 4 wooden, 140-130 B.C.E. (Lamboglia 1964); Sud Lavezzi B, France, 3 iron, 3 wooden, 10-30 C.E. (Liou 1982); Dramont D, France, 3 iron, 1 wooden, 40-50 C.E. (Joncheray 1975b); Cap Bear B, France, 6 iron, 1 wooden, 2<sup>nd</sup> – 3<sup>rd</sup> cent. C.E.; Capo Granitola D, Italy, 3 iron, 1 wooden, Late Roman (Parker 1992).

<sup>84</sup> Haldane 1990, 23-4.

surmises that stock-weighted anchors, those with lead stocks, were ideal for sandy beds while crown-weighted anchors, those of iron, were more suited for rocky bottoms, and that the iron anchor became preferred over the wooden anchor because of its versatility and not necessarily for its higher durability.<sup>85</sup> Eventually wooden anchors disappeared altogether and iron became standard.

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<sup>85</sup> Campbell 2012, 415-6.

### CHAPTER III

#### THE SMALL IRON OBJECTS

Concretions of various sizes are commonly found during the excavation of a shipwreck, but it takes a keen eye to be able to recognize on site exactly which of those will yield objects and which are essentially just rock.<sup>86</sup> For this reason, it is beneficial to raise everything so that judgments made on the seabed can be reexamined. Initial recognition in most cases proves difficult if not impossible, and it is necessary to begin assessing concretions only after they have arrived in the laboratory and have been x-rayed. With viable object concretions, a distinct outline will be visible in the radiographs, and with rock, the x-ray will appear hazy with no discernible features.

Being a stone carrier, it was hoped that the excavation of the Kızılburun shipwreck might provide an array of stone-working tools transported by a stonemason, much like the kit found among the concretions from the 1<sup>st</sup>-century C.E. Porto Novo shipwreck in Corsica, the discovery of which attests to the presence of a stone specialist accompanying the cargo.<sup>87</sup> At least one of the objects from Kızılburun has a connection to stoneworking, however as a result of my research, it seems that most of the identified tools can be linked to woodworking activities, essential for the maintenance and repair of the wooden hull. In this chapter, each of the small iron artifacts is discussed, beginning with what

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<sup>86</sup> Preliminary identification of small objects published in Carlson and Hamilton 2009 and Rash 2010; readdressed here with permission from INA and CMAC.

<sup>87</sup> Bernard et al. 1997, 53-8.

steps were taken to conserve them, followed by parallels to aid their identification.

## CHISELS

### *Flat Chisel*

Three iron concretions found in close proximity to each other (Lots 117.01, 150.02 and 790.01) seemed to belong to the same object (**CH 1**), although there were no clear joins in the concretions or the cast objects (Fig. 3.1). X-rays were deemed unnecessary since they were all broken at the ends, and an outline indicative of an iron object was noted within. Casting was simple since no corroded iron remained. The voids were flushed with acetone, one end was dammed with plasticine, and epoxy was poured into each concretion. Following mechanical cleaning, the three objects were painted since too little of the iron residue remained to naturally tint the epoxy resin.



Fig. 3.1: The three components (handle, shaft and blade from left to right) of **CH 1**.

At first, the thin shank resembled a file or rasp, but features soon emerged that eliminated both ideas. The middle section of the object can be identified as the shaft of a

chisel, which displays the same beveled edges present on the collection of tools and tool fragments from the Porto Novo shipwreck.<sup>88</sup> The Porto Novo wreck, dated to the second quarter of the 1<sup>st</sup> century C.E. or later by the presence of a sword sheath and a Tiberian coin minted in 27 or 28 C.E., was carrying a load of stones in various stages of finish, from crude blocks to semi-finished forms. The finds indicate that the shipment was accompanied by a stone worker with a kit of tools specific to stone carving. Two iron objects from the Porto Novo wreck mirror the shape seen in the Kızılburun chisel. The first example is described as a chisel used for stone cutting purposes, with an overall length of 40.0 cm and a section of approximately 2.0 cm in width. The shaft has beveled edges, giving it an octagonal shape when studying the cross-section. Toward the tip, the section becomes rectangular as the shaft flares out into a sharpened blade. In this case, the very tip of the blade has been blunted, by what the authors describe as a violent shock, which not only distorted the end but twisted the handle.<sup>89</sup>

The second object from the same wreck differs but still possesses the octagonal shank with rectangular blade, which flares outward where it attaches at the shaft, estimated from the scale drawing to be 5.0 cm thick. Although the object was broken into two pieces, its estimated original length is 1.43 m. The authors have classified this tool as a type of crowbar used in the movement of the marble blocks within the hold if they happen to shift during rough seas.<sup>90</sup> Although similar in shape to the Kızılburun chisel,

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<sup>88</sup> Bernard et al. 1997, Figs. 4a, 4b, 7c, 9e and 9f.

<sup>89</sup> Bernard et al. 1997, 63, Fig. 7c.

<sup>90</sup> Bernard et al. 1997, 60.

its larger dimensions must be taken into account. **CH 1** could not have been used in such a manner, since its shaft is not as robust and could not have handled the same amount of stress. It is possible to discount its identification as a prying device. Despite being used in a different capacity, the Porto Novo crowbar offers a parallel for **CH 1**'s overall shape: the shank is octagonal in section then changes to a blunt and robust shape toward the very end of the handle,<sup>91</sup> a feature that verifies the identity of the separate handle fragment from Kızılburun.

The Kızılburun chisel can also be compared to the finishing tools common to the ancient stonemason described by both Blagg and Rockwell.<sup>92</sup> Blagg studied carved stones in Britain and interpreted the tool type by comparing implements found in Roman contexts and known to have been used by ancient stoneworkers.<sup>93</sup> One such mason's chisel with a faceted shaft and very similar in shape to the Kızılburun chisel was found at Housesteads in England.<sup>94</sup> More recently, Rockwell's work attempts to marry modern technique with the ancient craft to establish a history of stone-working tradition, by consulting masons in multiple countries as well as blacksmiths responsible for tool manufacture and documenting tool marks visible on various pieces of sculpture.<sup>95</sup> These two works along with the archaeological parallels from Porto Novo and Housesteads support the identity of the Kızılburun chisel and suggest a purpose.

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<sup>91</sup> Bernard et al 1997, Fig. 4b.

<sup>92</sup> Blagg 1976, Fig. 1H-K; and Rockwell 1993, 56, 58-9.

<sup>93</sup> Blagg 1976, 153-4.

<sup>94</sup> Ward (1911, 199, Fig. 57 M) calls this example a mason's chisel.

<sup>95</sup> Rockwell 1993, see Notes for Chapter 3 and Chapters 16 and 17 for methods of documentation.

Moving toward the blade, the shaft begins to flatten, confirming that the tool is indeed a chisel. The preserved shaft has an octagonal cross-section which abruptly transitions to a rectangular section near the tip. Since the tip defines the type of chisel and its function, the blade fragment (Lot 790.01) identifies it as being a flat chisel, used as a multi-purpose tool in carving and finishing, as opposed to a tooth chisel with a serrated cutting edge ideal for fine detail work.<sup>96</sup> The handle concretion (Lot 150.02) was broken at both ends, so it is impossible to estimate the maximum original length or even join it to the shaft with positive accuracy. The globular nature of the handle prevents any more detailed descriptions of its features, but it appears round in section and lacks the beveled edges of the shaft.



Fig. 3.2: Arrows marking where defined edges reflect the original thickness of the blade.

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<sup>96</sup> Rockwell 1993, 40-1, 42-3 and Drawings 4 and 5.



The chisel from Porto Novo<sup>97</sup> provides a hint that Lot 790.01 is the blade portion of **CH** 1. Although it does not form any obvious joins to the shank, this cast is a viable shape for a chisel blade. It is slightly concave, eliminating the fleeting thought that it might be a knife blade, and the thickness at the broadest end, approximately 0.7 cm, closely mirrors the 1.0 cm thickness at the rectangular end of the shaft. Since the concretion in this case was broken at both ends, the epoxy replica has many imperfections due to erosion of the inner cavity, and no attempt was made to correct its appearance for fear of losing its natural dimensions and characteristics. The width tapers from 3.1 cm at the top, where it meets the shank, to 2.0 cm at the tip of the blade.<sup>98</sup> It is clear that the original thickness was 0.5 cm, due to an exposed and well-defined surface on a very small portion of the blade (Fig. 3.2), but the cast expands to a much thicker 1.6 cm, which is not indicative of its original size.

A problem to address with chisels is how to distinguish one used by a carpenter from one used by a stonemason. In fact, the chisel has a long history within the woodworking industry, dating back to the Stone Age, and was fashioned of stone, copper, bronze and finally iron.<sup>99</sup> According to R. Ulrich, the chisel is forged from a single bar of iron for heavy work, no matter if the intended material be stone or wood,<sup>100</sup> although, Blagg states that a carpenter's chisel is generally an iron blade attached to a wooden handle, whereas the mason's chisel is made of one solid piece of iron from the blade to the

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<sup>97</sup> The width of the chisel blade from Porto Novo measures 3.0 cm (Bernard et al. 1997, Fig. 7c).

<sup>98</sup> Bernard et al. 1997, 63.

<sup>99</sup> Goodman 1964, 195-6.

<sup>100</sup> Ulrich 2007, 26-8.

handle.<sup>101</sup> Solid metal chisels are rare,<sup>102</sup> and the socketed chisel is indeed a much more common find in general, especially within contexts alongside other carpenter's tools.<sup>103</sup> Taking this information into account, the Kızılburun chisel may have been a tool of the stone worker's trade, although this does not denote an exclusive use. Depictions of chisels used in woodworking, although few, do exist. An antefix, found in Rome and now in the British Museum, shows Argus using a chisel to shape the bow of the ship *Argo* under Athena's instruction.<sup>104</sup> On Trajan's Column, the use of a chisel is depicted in shaping rough logs (Scene 28) as well as in bridge construction with the shaping of components (Scene 12) and cutting a mortise into a beam (Scene 8).<sup>105</sup> It is not clear whether the chisels depicted in the aforementioned carvings were socketed or tanged rather than solid metal.

The solid metal chisel, found in the example from Kızılburun, is the oldest form and evolved according to use before a wooden handle was introduced.<sup>106</sup> It is probable that the presence of this type of chisel is related to the marble cargo, given that so few have been documented alongside dedicated woodworking tools. The flat chisel has a demonstrated use in stone working, and the find from Kızılburun might therefore be attributed to a tool kit necessary to the shipment of stone.

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<sup>101</sup> Blagg 1976, 164.

<sup>102</sup> Manning (1966, 14 and Fig. 10) documents one with an octagonal section and much longer, straight blade from Cumberland, United Kingdom.

<sup>103</sup> Christensen 2005, 69-70, Fig. 25; Evans 1894, 149, Fig. 15; Allison 2006, 141, 186-7, 276. 329, 343, 348-9, 452-3, Mutz 1980, 129-30, Fig. 5.

<sup>104</sup> Smith 1875, 98.

<sup>105</sup> Pollen 1874.

<sup>106</sup> Petrie 1917, 19-20.

### *Bar Chisel*

Lot 322.05 was a long, thin concretion broken at one end and a rim sherd of a plate attached. Upon cleaning in the laboratory, a clear rectangular cross-section was noted in the broken extremity. Following radiography, the object was further broken in half to facilitate cleaning. The lower portion was filled with epoxy first, and the other half was attached using plasticine to connect the two sections as well as bridge a sizeable gap missing in the concretion. The remainder of the cavity was filled and allowed to set before removing the concretion with an air scribe. The object that emerged (**CH 2**) is 37.7 cm in length, rectangular in section, and tapers to a point. Since the concretion was incomplete, the original length is not discernible.

It was theorized at first that it might be a bladed instrument, like a knife, but there are no sharp edges to indicate that it served this purpose: its cross-section would be triangular to reflect at least one sharpened edge. **CH 2** maintains its rectangular cross-section throughout as it tapers. No other concretions were found which might be portions of the same object. It was thought as well that the iron rod may represent a portion of a file, like one found in London measuring 20.3 cm in length,<sup>107</sup> but the surface lacks the characteristic striations, which should have been preserved in the epoxy replica (Fig. 3.3).

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<sup>107</sup> Painter 1961, 116, Plate L c.



Fig. 3.3: **CH 2** after casting.

Three objects of similar shape and size were excavated at the Bronze Age shipwreck at Uluburun in Turkey. Identified as bronze deep-bar chisels, they are rectangular in cross-section and taper to a point, ranging in length from 10.0 - 25.5 cm, in width from 1.5 - 2.7 cm and in thickness from 0.6 - 1.0 cm.<sup>108</sup> Another almost identical artifact made of iron was described among the large hoard of Roman tools cataloged from the three 2<sup>nd</sup>-century C.E. forts at Saalburg, Feldberg, and Zugmantel along the Roman *limes* in Germany. Pietsch classes the object as a chisel or wedge, with a rectangular cross-section, measuring 27.8 cm in length and tapering to a point.<sup>109</sup> It also closely resembles an object described as a fragment of a blade or chisel from Pompeii.<sup>110</sup> Petrie states that a bar chisel was ideal for cutting mortises, with its longer size useful for leverage in removing wood chips from the mortise.<sup>111</sup>

<sup>108</sup> Pulak 1988, 17-19, Fig. 15.

<sup>109</sup> Pietsch 1983, 41, 105, Plate 13.

<sup>110</sup> Allison 2006, 187, cat. no. 1317, Fig. 32.4 and Plate 86.15.

<sup>111</sup> Petrie 1917, 20.

## NAIL REMOVER

Initially, casting **NR 1** (Lot 741) seemed a relatively simple task; however, it became obvious that any object within could not be identified easily using the x-ray alone (Fig. 3.4). It was decided that the best option was to break open the small dense concretion, as opposed to cutting it with a saw. A break fits together cleanly when reconnecting the fragments, whereas sawing leaves a small gap. However, instead of breaking cleanly apart, a hole was punched into the cavity, which prevented a thorough study of the shape of the void. Through this hole, it was possible to clean out what seemed to be the extent of the cavity, and epoxy was poured inside and allowed to harden. During mechanical cleaning, the handle portion was revealed first followed by the two claws, and it was assumed at the time that the tool was a claw hammer. Additional research suggests that it is not a hammer at all, but a nail remover. The handle ends in a blunt surface, which itself can be hammered, providing extra force when trying to free a particularly stubborn nail.<sup>112</sup>

In 1984, a shipwreck from the 1<sup>st</sup> century C.E. was discovered and named Cala Culip IV after the point where it was found along the Spanish coastline. Among the hundreds of broken Dressel 20 amphoras and terra sigillata pottery,<sup>113</sup> excavation of the ship produced a concretion of indeterminate shape. Not until it was x-rayed did archaeologists have an idea of its contents. The void within the concretion proved to be

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<sup>112</sup> Pietsch 1983, 52, 110.

<sup>113</sup> Nieto et al. 1989, 11-18, 59-70.

a once iron tool, and following filling with silicone and removal of the surrounding encrustation, the authors were able to identify the object as a tool whose purpose was to remove nails from wood.<sup>114</sup> Similar in form, the two examples do have differences in their details. The nail remover from Cala Culip IV is slightly longer, measuring an approximate 22.0 cm, while the Kızılburun example measures 17.3 cm, and the example from Cala Culip IV appears more angular compared to the delicate curvature of that from Kızılburun (Fig. 3.5).



Fig. 3.4: X-ray of nail remover (top) with majority of object obscured by dense concretion except uppermost portion of handle, and as it appeared before manual cleaning (bottom).

<sup>114</sup> Nieto et al. 1989, 212, Figs. 29 D and 153.2.



Fig. 3.5: Two views of **NR 1**, after casting.

In fact, Petrie categorized the nail remover as a shortened form of a crowbar, having forked ends as well as a chisel end, three of which were found at Pompeii.<sup>115</sup> Five nail removers were identified among the Roman tools excavated from three forts at Saalburg, Feldberg, and Zugmantel in Germany, ranging in length from 16.0 cm to 20.2 cm, the smallest only slightly shorter than that from Kızılburun. The three shortest would only have been suitable for light work, such as for nail removal, but not for prying apart larger, heavier objects.<sup>116</sup> The Kızılburun nail remover may have also been useful on the ship in loading and unloading the marble grave *stelai* and other marble blocks,<sup>117</sup> by

<sup>115</sup> Petrie 1917, 41, Plate XLVII 40-2.

<sup>116</sup> Pietsch 1983, Plate 17, 420-2.

<sup>117</sup> Carlson 2007, 5.



using the claws to pry the stones away from a surface on which they rested and allowing enough space to place a strap or hand to lift them.

The nail remover, the ancient name of which is unknown, first appears at the beginning of the Roman Empire and by Late Antiquity has disappeared altogether,<sup>118</sup> so the Kızılburun example may be the earliest yet found. The claw hammer being a Roman invention sheds some light on the appearance of these forked tools around the same time.<sup>119</sup> It can be safely said that forked crowbars, claw hammers, and nail removers are the product of the same breakthrough in tool engineering: the use of leverage in prying.

#### AXE-ADZE

**AA1** (Lot 190) originated as a large, dense concretion. The digital x-ray, of extraordinary clarity, showed a definite outline of an adze blade and another end which was unclear until after mechanical cleaning. Along the top of the adze blade sat an unclenched copper nail which appeared to have been caught in the iron concretion bleed as it corroded (Fig. 3.6). The casting of this particular tool proved to be fairly simple. It was broken into three sections, avoiding the handle, so that it could be cleaned thoroughly. There remained a well-preserved original surface and only a black residue of corrosion product. Epoxy was poured into the blade portions first and allowed to harden. The handle was then attached to one of the blades, and more epoxy was added

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<sup>118</sup> Pietsch 1983, 52-3.

<sup>119</sup> Petrie 1917, 40-1, Plate XLV 108 and 109; see also Ulrich 2007, 51; Goodman 1964, 202.

until the break was covered and sealed off by the hardened resin.



Fig. 3.6: X-ray of **AA 1** (top) showing nail concreted to adze blade, and as it appeared before mechanical cleaning (bottom).

The two sections were reconnected, and a small amount of wet epoxy was used to join the fragments together. Mechanical cleaning revealed the tool to have two blades and a

portion of the handle left intact thanks to the iron corrosion, with the original curvature of the top of the wood preserved. Another fragment of wood, possibly matting, was found with the upper point of the axe blade embedded in it (Fig. 3.7). The heavily concreted copper nail was separated and given Lot 190.02.



Fig. 3.7: **AA 1** after cleaning, with wood fragment concreted to axe blade (bottom), and portion of wooden handle preserved due to iron corrosion (top).

The object revealed by casting is a double-bladed instrument with one blade (an axe) parallel to the handle and the other (an adze) perpendicular to the handle. The overall length measures 30.9 cm. The axe-adze combines the usefulness of two of the oldest

types of woodworking tool.<sup>120</sup> This combination tool, first made of bronze, appeared in Minoan contexts around 1700-1400 B.C.E. and was widespread throughout the Roman world.<sup>121</sup> This tool also speaks of Roman ingenuity and their penchant for combining two tools into one: the claw hammer, mentioned above, the adze-pick,<sup>122</sup> the axe-hammer,<sup>123</sup> the adze-hammer,<sup>124</sup> and the adze-plane,<sup>125</sup> just to name a few. The Latin word for an axe-adze *ascia* often referred to any one of the multi-functional, bladed tools.<sup>126</sup>

The iron axe-adze had varied uses. One example was found among agricultural implements at the villa of P. Fannius Synistor at Boscoreale, dating to 79 C.E., when Mt. Vesuvius covered the area. Originally published as a mattock, it might have been used to clear land of heavy roots and vines.<sup>127</sup> The adze-hammer was widely used in the stone cutting industry, and the axe-adze as a variation was suitable for both quarrying and dressing stone, especially since evidence of the individual blades can be seen on carved stones from Britain.<sup>128</sup> Another was unearthed in the Israeli site of Qumran, which the publisher ascribes to Hellenistic influence in the region.<sup>129</sup> Very closely resembling the axe-adze from Kızılburun, the example excavated at Pompeii was better suited for

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<sup>120</sup> Ulrich 2007, 16.

<sup>121</sup> Goodman 1964, 21.

<sup>122</sup> Blagg 1976, Fig. 1A.

<sup>123</sup> Goodman 1964, Fig. 14b.

<sup>124</sup> Goodman 1964, Fig. 15.

<sup>125</sup> Ulrich 2007, 16.

<sup>126</sup> Smith et al. 1890; Ulrich 2007, 274.

<sup>127</sup> De Cou and Tarbell 1912, 149-52, 211; Harvey 2010, 699, 706, Fig. 18.

<sup>128</sup> Blagg 1976, 156-9.

<sup>129</sup> De Vaux 1959: 405, Fig. 1.

working with wood, due to its small size (Fig. 3.8).<sup>130</sup> Five were cataloged among the Roman tools excavated at Saalburg, Feldberg, and Zugmantel, ranging in length from 25.9 cm to 46.0 cm, which may indicate variations in use.<sup>131</sup>

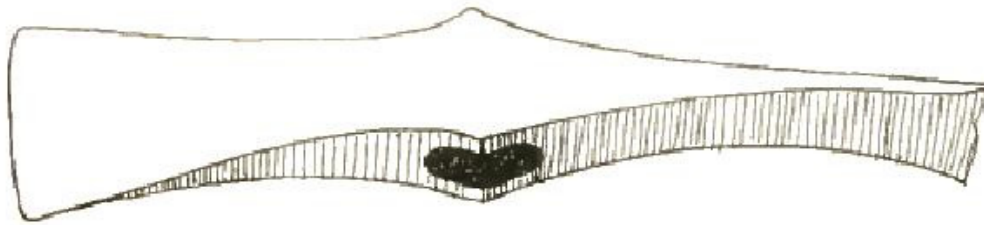


Fig. 3.8: Axe-adze from Pompeii (after Petrie 1917, Plate XIV, 63).

Known among Roman woodworkers,<sup>132</sup> the axe-adze held a natural place in the tool kit of a shipwright. The grave relief of Publius Longidienus found at Ravenna, Italy shows the deceased wielding an adze-plane, a variation on the axe-adze combination, in shaping the timbers of a ship.<sup>133</sup> Examples have been identified from numerous ancient shipwrecks in the Mediterranean, indicating that the axe-adze was not only important during the initial building stages but also handy for repairs during a voyage. The earliest specimen from a shipwreck, dating to ca. 1200 B.C.E., was found at Cape Gelidonya in Turkey and is made of bronze. Although found intact and possibly intended for shipboard use, the bronze axe-adze was being transported among many other broken

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<sup>130</sup> Petrie 1917, 15, Plate XIV 63.

<sup>131</sup> Pietsch 1983, 88-9, Plate 3 43-47.

<sup>132</sup> Goodman 1964, 24.

<sup>133</sup> Ulrich 2007, 18, Fig. 3.9.

tools that represent a cargo of scrap bronze destined to be melted and reformed.<sup>134</sup>

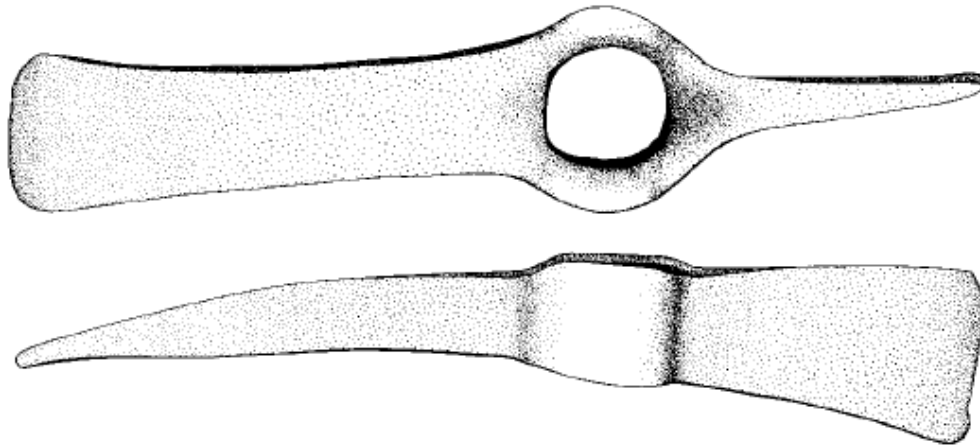


Fig. 3.9: One of the axe-adzes from the 7<sup>th</sup>-century C.E. shipwreck at Yassiada, Turkey (after Katzev 1982, Fig. 11-9, Fe 12; used with permission from TAMU Press).

Iron axe-adzes have been found on the following wrecks in France: the late 2<sup>nd</sup>-century B.C.E. shipwreck at Grand Ribaud,<sup>135</sup> the two 1<sup>st</sup>-century B.C.E. ships at Chrétienne,<sup>136</sup> Cap Gros C, dating to the same century,<sup>137</sup> and in Turkey: the 4<sup>th</sup>-century C.E. Yassiada shipwreck,<sup>138</sup> and the 7<sup>th</sup>-century C.E. Byzantine ship also from Yassiada, which carried two (Fig. 3.9).<sup>139</sup> It should be noted that throughout the ages, the general shape remains the same, although specific differences can be noted in the shape of the outer portion of the shaft holes and the angle of the adze blade in relation to the handle. The abundance

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<sup>134</sup> Bass 1961, 273-4, Fig. 26.

<sup>135</sup> Carrazé 1975, Fig. 6

<sup>136</sup> For Chrétienne A, see Dumas 1964, 107; for Chrétienne J, carrying two, see Pomey et al. 1988, 44.

<sup>137</sup> Joncheray 1991, 64-7.

<sup>138</sup> The axe-adze originally attributed to the 17<sup>th</sup>-century C.E. shipwreck nearby (Bass and van Doorninck 1971, 37) may in fact belong to the Late Roman assemblage (Pulak 2008, pers comm).

<sup>139</sup> Katzev 1982, Fig. 11-8 Fe 12 and Fe 13.

of axe-adzes found on ancient wrecks is a testament to the utility of the tool during the ship's journey and to the benefit of having two tools combined into one, which on a ship, where space is at a premium, is a simple practicality.

## DOUBLE AXES

### *AX 1*

In 2006, a very heavy concretion (Lot 394) was excavated just upslope from Drum 1, described by Dr. Kristine Trego as a “dog bone” on account of its shape. The object was thought to be yet another iron concretion, but after a failed attempt to x-ray it within the Nixon Griffis Laboratory, it was taken to Bodrum Özel Hospital. The hospital’s digital x-rays revealed that a substantial amount of metal remained within the shell, thus accounting for its weight. It was clear from the x-ray that the object was a double-headed axe (Fig. 3.10). At the time, it was thought that the artifact (**AX 1**) within was made of bronze, a more noble metal and less apt to total corrosion, but it lacked the green crust characteristic of corroded copper alloys,<sup>140</sup> also seen in the abundance of copper nails at Kızılburun.<sup>141</sup> After part of the dense, grayish concretion layer was removed, it was found that the object is actually made of iron because it was still magnetic.

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<sup>140</sup> Cronyn 1990, 216-17.

<sup>141</sup> Carlson and Atkins 2008, 25.



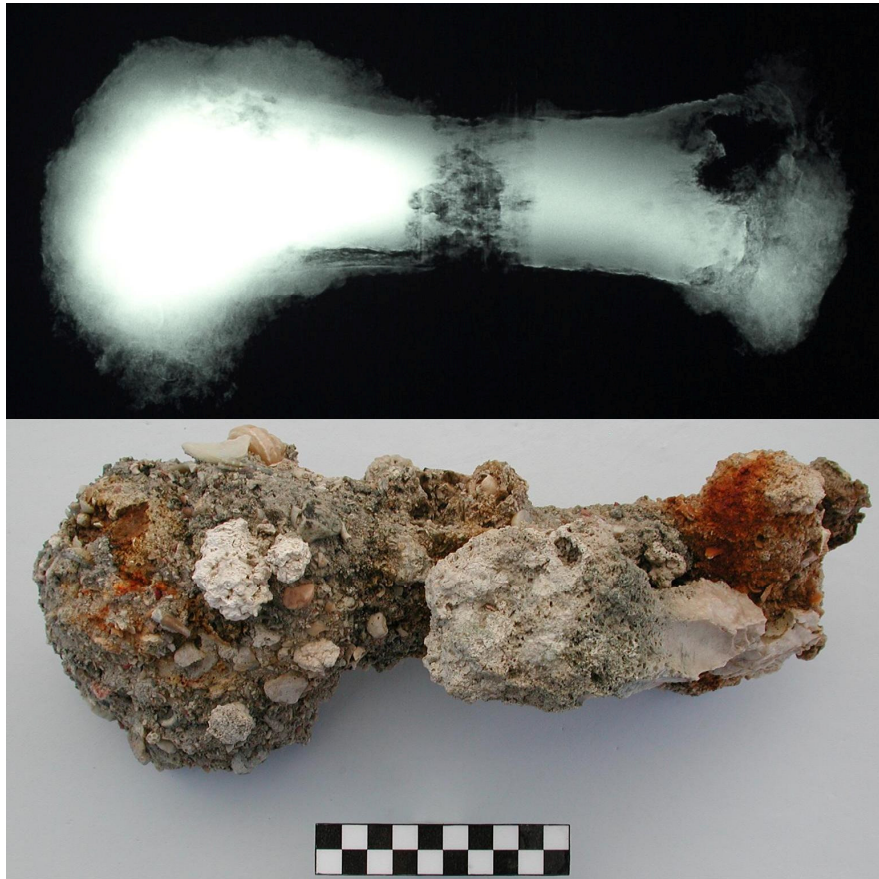


Fig. 3.10: X-ray of **AX 1** (top) with iron indicated by the white portions of the image, and as it appeared before conservation (bottom) (after Rash 2010 Fig. 2; used with permission from CMAC).

Several factors must be considered when attempting to explain why one iron artifact remains metallic while others from the same site are reduced to a void within a concretion. Complete burial prevents those bacteria reliant upon oxygen from attacking the metal, which may ensure at least partial survival of the artifact; however, in the presence of seawater, anaerobic bacteria can still inflict damage. Additionally, burial beneath a compact overburden protects an object from environmental disturbances, such

as the action of underwater currents, and may aid in survival.<sup>142</sup> The excavator noted that much sand had been removed during the course of the season before the axe was uncovered, so deep burial alone may be accountable for its condition. Other elements such as high salt content, fluctuating temperatures, and sunlight commonly affect the preservation of deposits from land excavations but cannot be accounted for at Kızılburun, being that salts occur detrimentally in conjunction with moisture, temperatures fluctuate very little, and at 45 meters, the site is deep enough not to be affected by sunlight.<sup>143</sup>

Another factor is the formation of an electrochemical cell. Corrosion occurs readily when two metals are deposited together, and one of the metals is less noble, thus anodic to the other. The more noble of the two metals, or the cathode, is protected at the expense of the anode, which becomes subject to deterioration when the two objects are submerged in an electrolyte (in this case seawater). The electrochemical cell between different metals offers an explanation of why the axe survived where other iron objects did not. The same cell can also form between areas of the same object with varying purities.<sup>144</sup> The portions of the axe that seem to have deteriorated the most are the sharpest parts of the blade, which is indicative of metal corroding more readily at the point which receives the most stress, whether during fabrication or during its use-life.<sup>145</sup>

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<sup>142</sup> Cronyn 1990, 24-8.

<sup>143</sup> Cronyn 1990, Fig. 2.2.

<sup>144</sup> Hamilton 2010, Metal Conservation: Preliminary Steps.

<sup>145</sup> Rehder 1992, 46.

An additional option that cannot be ruled out is that **AX 1** may be intrusive. The double axe is a common tool that exists even in modern times, and it could be a much later intrusion into the Kızılburun wreck assemblage, which may account for its metallic state. According to the excavator, **AX 1** was found buried beneath a heavy layer of sand and in close context with copper nails, which suggests that the axe should be included as part of this ship's artifact assemblage. Luckily, a portion of the handle from **AX 1** survives within the concretion. Once it has been desalinated, the remainder of the concretion can be removed, and a sample of the organic remains can be tested to determine its age.

Since this artifact was almost entirely preserved, it was necessary to conserve it in a different manner than the other concretions, which when x-rayed proved to be devoid of any remaining iron. It was decided, based on the assumed age of the iron, to remove the chlorides passively using a sodium hydroxide solution. The densest portion of the heavy concretion was removed in order to ensure that chlorides were being removed from the object and not the concretion alone;<sup>146</sup> however, a layer of encrustation was left in place in order to protect the original surface. The object was then placed in a 1% sodium hydroxide solution and chlorides were monitored periodically for 12 months using the standard mercuric nitrate titration method, without a solution change. Upon testing in January 2010, chlorides were found to be very high, almost equal with that of the local tap water, so it was deemed necessary to replace the solution, this time using 2% sodium

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<sup>146</sup> Cronyn 1990, 198.

hydroxide dissolved in deionized water.<sup>147</sup> Although the gentlest way of removing chlorides when concerned about the fragility of an object, passive removal using an alkaline solution at room temperature is also the slowest method. It relies heavily upon continuous chloride monitoring and periodic change of solution.



Fig. 3.11: **AX 1** following the removal of concretion from one surface.

In February 2011, after 12 months of titrations revealed very little change in the chloride content, the concretion was removed from one face of the axe, exposing the iron (Fig. 3.11). It is probable that the heavy concretion covering the iron prevented removal of

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<sup>147</sup> 2% sodium hydroxide is suggested by Hamilton 2010, Iron Conservation: Part II – Experimental Variable and Final Steps, Water Diffusion

soluble salts from the metal itself, and further action was necessary.<sup>148</sup> Using an air scribe to penetrate the dense encrustation, one blade slowly emerged. The iron surface proved much more delicate than at first glance: it easily chipped and delaminated under the duress of the pneumatic tool, thus much care was taken to ensure the least amount of disturbance of the original surface.

After revealing the metal surface, the axe was returned to the alkaline solution. Judging from the shape of the concretion, it seems that a portion of the wooden handle remains intact, and it was deemed best left sealed within the encrustation, since the exposure of organic matter to sodium hydroxide can be detrimental and may cause its dissolution. Following desalination, the remainder of the concretion surrounding the handle can be removed, and additional information about its preservation should come to light. When chloride levels have reached a stable and low count, it will then be removed from solution, boiled in deionized water in order to remove any precipitate remaining from the hydroxide soak, painted with tannic acid to prevent further corrosion and sealed with microcrystalline wax to protect it from environmental fluctuations.<sup>149</sup>

The double axe appears throughout history in various cultures, so it would be impractical to include here every archaeological example. Although the single bladed axe was more common,<sup>150</sup> double axes were also part of the ancient tool kit, and iron examples similar

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<sup>148</sup> North and Pearson 1978, 179.

<sup>149</sup> Hamilton 2010, Iron Conservation: Part II – Experimental Variable and Final Steps.

<sup>150</sup> Ulrich 2007, 22.

to the Kızılburun axe have been illustrated by Petrie from Dodona, Pompeii, and Egypt (Fig. 3.12).<sup>151</sup> Two double axes were excavated from two Etruscan burials near Vetulonia, Italy, an unusual find given that tools are not usually included with grave goods.<sup>152</sup>

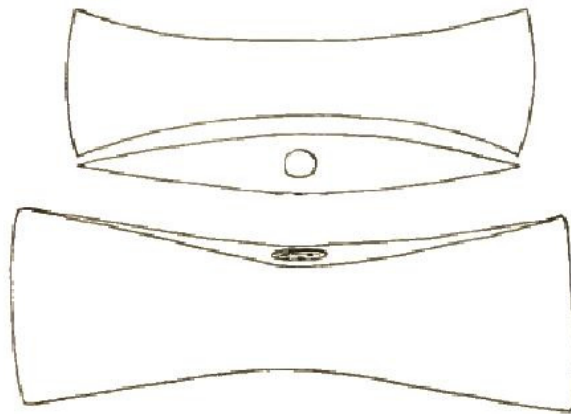


Fig. 3.12: Double axes from Dodona (top) and Pompeii (bottom) (after Petrie 1917, Plate XII 39 and 40).

Within the realm of shipwreck sites, while many single-bladed axes have been documented, only a few double-axes have been excavated. The earliest double axes found among the wreckage of a ship came from the Bronze Age wreck at Uluburun in Turkey and were made of bronze.<sup>153</sup> One iron double axe was found among the concretions at the 1<sup>st</sup>-century C.E. Chrétienne H shipwreck in France,<sup>154</sup> and two were located among the wreckage of two presumed Roman shipwrecks on the Carmel Coast

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<sup>151</sup> Petrie 1917, Plate XII 39 and 40, Plate XIII 45.

<sup>152</sup> Spranger 1927, 204.

<sup>153</sup> Bass 1986, 274 and 292.

<sup>154</sup> Santamaria 1984, Fig. 29.

of Israel, dating to the 3<sup>rd</sup> and 4<sup>th</sup> centuries C.E.<sup>155</sup> Three additional axes were excavated from the 7<sup>th</sup>-century C.E. ship at Yassiada in Turkey (Fig. 3.13), one of which was missing a blade, and one of which had an associated nail that had been inserted into the end of the handle to ensure a tight fit into the shaft hole.<sup>156</sup>

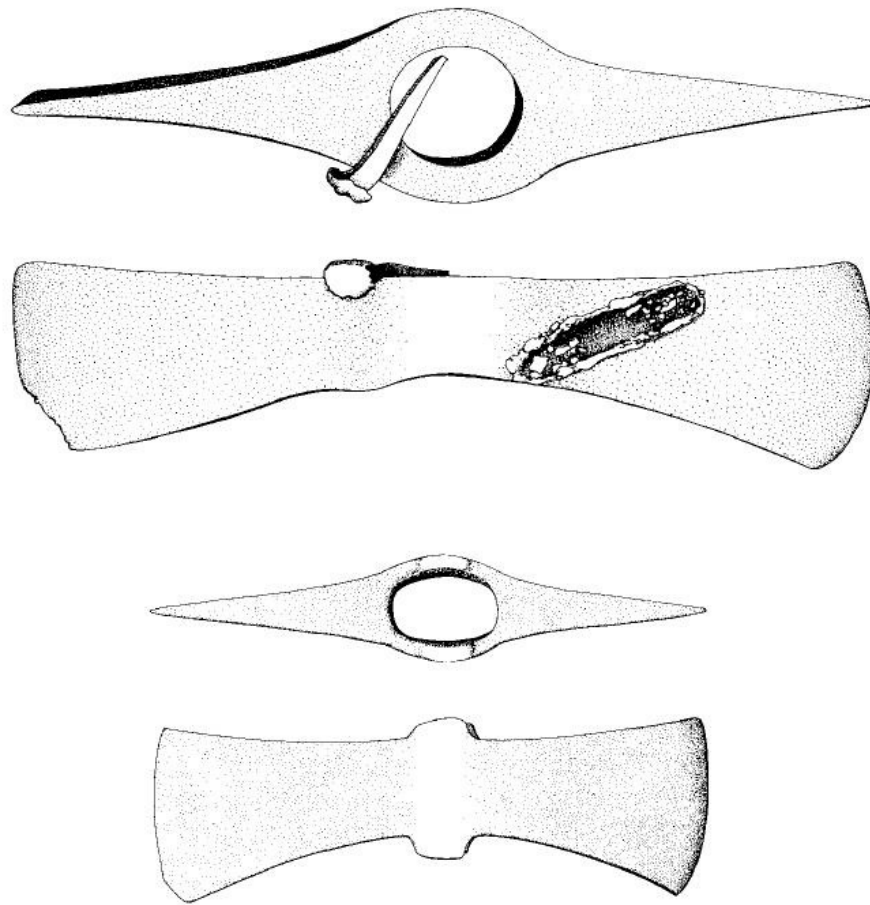


Fig. 3.13: Two of the double axes from the 7<sup>th</sup>-century shipwreck at Yassiada, Turkey (after Katzev 1982, Fig. 11-9, Fe 9 and 11; used with permission from TAMU Press).

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<sup>155</sup> Galili et al. 2010a, 75-6.

<sup>156</sup> Katzev 1982, 237-9, Fig. 11-9.



The axe has been used for millennia and is one of the oldest tools. It has been manufactured from every material imaginable, including antler, stone, copper, and finally iron, and it continued to evolve until modern times. A copper axe was found buried in the Swiss Alps with the mummified body of a Late Neolithic man, known as Ötzi. The burial, estimated at 5,100 – 5,350 years old, either suggests that the axe was a valuable object to that individual or that the man was a high-ranking warrior, or both.<sup>157</sup> As a utilitarian improvement, a theory behind adding a second blade was the practicality of having a backup blade in case one became too dull for use.<sup>158</sup> It also may have been common to keep one blade purposefully sharper than the other, for cutting, while the dull blade could be used for splitting. Incidentally, a double-bladed axe is beneficial in tree-felling due to its ease of sharpening in the woods. One blade is embedded firmly into a stump, while the other is worked, eliminating the need to return to a workshop for honing,<sup>159</sup> a need that would have been even more frequent with a bronze axe.<sup>160</sup> As a part of the tool kit on any given ship, it had many functions, such as chopping firewood or shaping a timber for a repair, and in an emergency, it would be very useful in cutting away damaged rigging or masts.<sup>161</sup>

It would be impossible to speak of the double axe without mention of its prevalent use in the ancient world as a religious symbol. The Minoans can be credited with the

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<sup>157</sup> Rollo et al. 2002, 12594.

<sup>158</sup> Goodman 1964, 12-38.

<sup>159</sup> Ulrich 2007, 22; Goodman 1964, 38.

<sup>160</sup> Hodge 1985, 307.

<sup>161</sup> Galili et al. 2010a, 75-6.

application of a double axe in ceremonial contexts around 2600-2000 B.C.E., when one was included among the grave goods of the departed.<sup>162</sup> A large collection of more than 30 gold and silver double axes was unearthed in Arkalochari Cave on Crete in the 1930s. These votive offerings, dating to the middle of the second millennium B.C.E., were miniatures, with the heaviest weighing a mere 21.5 g.<sup>163</sup> Many other examples, found almost exclusively outside the Mediterranean, have been found with holes too small to fit a handle or too irregularly-shaped to serve a purpose, and thus it can be concluded that they functioned as votives.<sup>164</sup> Images of the double axe occur repeatedly among the iconography of Labranda, an ancient city in Turkey, and there is little doubt of its etymological connection to the Lydian *labrys*,<sup>165</sup> the history of which is described by Plutarch.<sup>166</sup> In Asia Minor, the symbol of the double axe was passed down through the ages, depicted in association with both Hittite and Assyrian deities, predating the Hellenistic affiliation with Zeus<sup>167</sup> and a host of other gods and goddesses outside of Caria.<sup>168</sup> In fact, the double axe appears in Etruscan iconography as well, in the form of vase paintings, reliefs on funerary urns, grave *stelai*, bronze mirrors, votive offerings, and coins.<sup>169</sup>

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<sup>162</sup> Goodman 1964, 20-1.

<sup>163</sup> Robinson and Blegen 1935, 134-6.

<sup>164</sup> Petrie 1917, 13-14.

<sup>165</sup> Alkim et al. 1951, 15.

<sup>166</sup> Plut. *Mor. Quaest. Graec.* 45.

<sup>167</sup> Stark 1958, 344.

<sup>168</sup> Waites 1923.

<sup>169</sup> Spranger 1927, 202-4.

## AX 2

The casting of **AX 2** (Lot 824) proved very simple, especially since the concretion was already broken in situ. It was x-rayed first, even though the cavities appeared to be well-defined and in good condition. The image produced from the x-ray was the unmistakable outline of a double axe. Both halves of the concretion were cleaned of all the sediments which had been deposited inside, and epoxy was poured easily into both halves, filling them. When the epoxy had reached a stage during hardening when it was still sticky but solid enough to move without leaking, the two sections were affixed together, and the hardening epoxy flowed together to seal the joint between them.

Mechanical cleaning proceeded normally, but it was quickly ascertained that a portion of the handle remained intact and would need to be addressed. Being that the axe handle had been so heavily impregnated with iron salts during the corrosion of the metallic blade, sucrose was deemed to be an appropriate treatment for the wood. The cast was placed in five liters of reverse osmosis water along with 0.1% Kathon, a biocide that discourages fungal or bacterial growth during the course of treatment. A 0.2% increment of sugar was added every day for four days, until it was decided that a larger increment would be desirable in order to speed treatment. The solution was then increased by increments of 2% for 14 days until the solution, measured using a refractometer, reached a concentration of 20%. After 14 days, additions were made at a 4% daily increment until the concentration reached a saturation of 70%. The axe was allowed to sit for an additional six months in the solution until it was removed for slow, controlled drying. It was placed in a closed container atop stainless steel screening so that the excess sucrose

could drip off, and the axe was periodically turned in order to prevent the sugar from pooling at the surface. After a period of 12 weeks, the sugar had completely crystallized, with no more liquid sugar pooling. The wood was stable, and the axe was removed from the container. No shrinking of the wood was observed.



Fig. 3.14: **AX 2** after undergoing conservation for the handle.

Attention was turned toward perfecting the cast. There had been some epoxy leaking during casting, so it was necessary to grind down the extra epoxy in order to mimic the surrounding surface. Air bubbles were visible within the cast, and these were filled using more liquid epoxy simply pumped into the imperfections. The new areas as well as the sanded portions were painted to match the natural iron-stained surfaces of the cast, and the object was deemed complete (Fig. 3.14).

Considering the fact that there is no evidence of a Hellenistic axe narrowing so drastically toward the handle, **AX 2** seems to be a later intrusion. It was also found approximately 20 m west of Drum 1 in area P<sup>170</sup> among a scatter of broken pottery distinguished by the combed clay characteristic of Late Roman and Byzantine ceramics, much like the amphoras from the 4<sup>th</sup>-century C.E. shipwreck at Yassiada.<sup>171</sup> It is likely that **AX 2** belongs to a later ship, which seems to have broken up among the rocks and peppered the seabed with its cargo.



Fig. 3.15: **FB 1** after separation from stock.

## IRON BAR

When studying the x-ray of anchor stock section ABX-8, there was a vague rectangular shape visible at an approximate 45° angle to the stock. The outline appeared rectangular,

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<sup>170</sup> Datum P was placed here (hence the area name) with an attempt to map the area, but it is not shown on a site plan, since ceramics found in here were decidedly later in date.

<sup>171</sup> Bass and van Doorninck 1971, 34, Plate 2 Fig. 8-12.

and because of its dense white appearance in the x-ray, it was thought to still be metallic. The identity of the object was unclear, and it was not until the stock was thoroughly cleaned with a pneumatic chisel that the two pieces could be separated and the unidentified object studied (Fig. 3.15). After removal from the stock concretion, it was discovered that the small, roughly rectangular flat iron bar (**FB 1**) is indeed still metallic and measures 23.5 cm in length, 4.7 cm in width and has a thickness of approximately 1.0 cm. **FB 1** was placed in a 2% sodium hydroxide solution, dissolved in reverse osmosis water, to complete passive desalination, as described above for **AX 1**. Following a period of 12 months, when the chloride content of the iron reached an acceptable measure, the bar was boiled, painted with tannic acid and sealed against the elements with Paraloid B72 to prevent further corrosion.

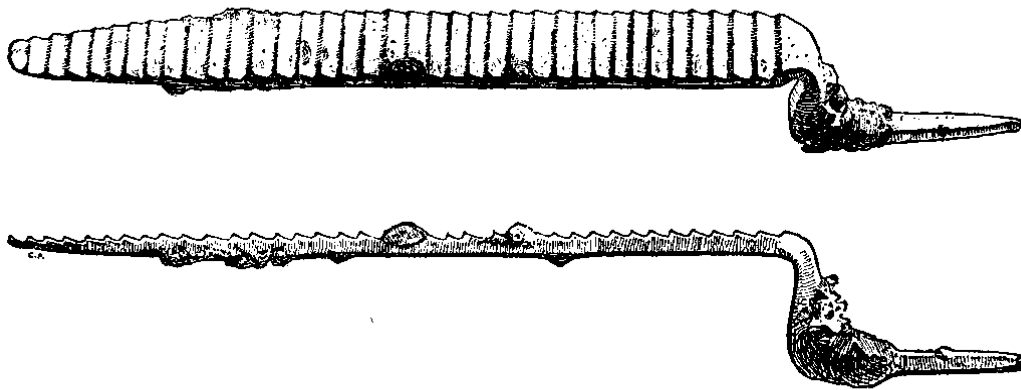


Fig. 3.16: File from Silchester (after Evans 1894, Fig. 19).

The function of this artifact remains unknown. Being found in association with the anchor stock seems to hold no clue to its use, and the relationship of the bar to the

adjacent thin strip of wood, described in the previous chapter, remains a mystery. As a tool, the iron bar was thought to resemble a file or rasp, but it lacks the characteristic teeth or serrations necessary for abrading a surface. One file with distinct teeth was found at Silchester, England in 1890 (Fig. 3.16), with similar dimensions (19.0 cm x 2.2 cm), although it was attached to a handle, evidence which is lacking for **FB 1** from Kızılburun.<sup>172</sup> Another file excavated in London dating to the 2<sup>nd</sup> century C.E. has striations across the blade, which are less proud of the surface than the Silchester file, but the two share a tapering shape and an indication of having a handle.<sup>173</sup> Two additional files from the 3<sup>rd</sup>-century C.E. site at Augst, Switzerland lack teeth and are curved toward the end of the file, but the triangular cross-sections and curvature discount them as strong parallels.<sup>174</sup> A rasp from the same site is flat on one side and domed on the other, producing a semi-circular cross-section, and had a handle as well.<sup>175</sup> **FB 1** also vaguely resembles four plane irons excavated at Augst. The largest measures 23.5 cm in length, 2.9 cm in width and 0.4 cm in thickness. These rectangular, flat iron bars are sharp at one end, which when inserted into a plane function to smooth out the surface of wood.<sup>176</sup> With the lack of a sharpened end, **FB 1** does not fit this description either.

The early 3<sup>rd</sup>-century C.E. Plemmirio B wreck in Italy was carrying a one-ton load of iron ingots. However, the dimensions of the original ingots, which were divided into

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<sup>172</sup> Evans 1894, 152.

<sup>173</sup> Painter 1961, 116 and Fig. Lc.

<sup>174</sup> Mutz 1980, 121-3, Fig. 2.4 and 5.

<sup>175</sup> Mutz 1980, 123-5, Fig. 2.6.

<sup>176</sup> Mutz 1980, 125-26, Fig. 3.7-10.



two types ranging from 40.0 - 60.0 cm and 90.0 - 115.0 cm in length, are much longer. The sectional measurements of those ingots also reflect a more robust, almost square shape,<sup>177</sup> whereas the Kızılburun bar is flat. Forty-eight iron bars were analyzed from 11 different Roman shipwrecks off the coast of Saintes-Maries-de-la-Mer in the south of France, and while a few of those bars are nearer in length, the sections are still too thick to be parallels for the example from Kızılburun.<sup>178</sup> Since there was only one bar at Kızılburun, it is doubtful that it constituted cargo and therefore likely served some function aboard the ship. However, being that iron can only be worked at a high temperature, it is highly doubtful that a piece of scrap iron would be useful to the crew. The nearest parallel was found on the 1<sup>st</sup>-century B.C.E wreck at Cap del Vol in Spain and was found in close proximity to two bronze bushings that were part of the ship's bilge pump. The author surmised that this bar, measuring 6.0 cm in length and 2.5 cm in width, was part of the ship's anchor, although heavy looting at the site may have obscured its true purpose.<sup>179</sup>

## IRON FASTENERS

Three iron nails (**FN 1**, **FN 2**, and **FN 3**) are among the objects cast from the wreck, but none has produced a complete set of dimensions. All three nails are roughly square in cross-section and taper toward one end, which can be assumed to be the tip even though none is preserved at the extremity (Fig. 3.17). The three nail concretions were all

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<sup>177</sup> Gibbins 1986, 290-2, Figs. 27 and 28.

<sup>178</sup> Pagès et al. 2011, 1234-5.

<sup>179</sup> Foerster 1980, 245.

broken, so casting involved simply pouring epoxy into the exposed void and letting it harden. **FN 2** had been used, evidenced by the bend or clench in the shaft as well as the wood remains attached to the shaft, while **FN 1** and **FN 3** appear to have been unused. The implications of these finds are discussed further in a separate M.A. thesis analyzing the hull remains.<sup>180</sup>



Fig. 3.17: **FN 1** (top), **FN 2** (middle), and **FN 3** (bottom).

One of the most important tools of the woodworking trade is the fastener, and more

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<sup>180</sup> Littlefield 2012.

specifically, the nail. Before 1800 when it was discovered that nails could be cut from an iron plate, all nails were hand-forged by a blacksmith, which was time-consuming and expensive. An iron rod was hammered and cut to the necessary length, then the rod was inserted into an anvil or a swage block, leaving part of the heated shaft protruding, which was then hammered flat into the shape of a head. An example of a nailer's anvil was found at Kreimbach in Germany, and the smaller tool known as the nail header has been identified from excavations at Silchester in England and Saalburg, Germany.<sup>181</sup> A hoard of 900,000 nails was found at a late 1<sup>st</sup>-century C.E. fort at Inchtuthil, Scotland. The consistency in the sizes and quality of the nails speaks to the organization in the supply chain of this basic implement within Roman Britain.<sup>182</sup>

Shipwrights of the Roman period in Britain were using iron nails extensively in the construction of their vessels.<sup>183</sup> The earliest datable appearance of iron nails in Mediterranean shipbuilding is found in the late 6<sup>th</sup>-century B.C.E. shipwreck at Gela in Italy,<sup>184</sup> and two late 6<sup>th</sup>-century B.C.E. shipwrecks from Marseilles, France (Jules Verne 7 and César 1)<sup>185</sup> thus marking the introduction and slow transition to iron fasteners in ship construction in that region. The 2<sup>nd</sup>-century B.C.E. shipwreck Jeune-Garde B at Porquerolles, France had iron nails driven through its treenails, attaching the planking to

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<sup>181</sup> Mercer 1975, 235-41, Figs. 204 and 205.

<sup>182</sup> Tylecote 1976, 53-4.

<sup>183</sup> Blackfriars ship, 1<sup>st</sup> cent. C.E. (Marsden 1965a); New Guy's House boat, 2<sup>nd</sup> cent. C.E. (Marsden 1965b); County Hall ship, 3<sup>rd</sup> cent. C.E. (Marsden 1974).

<sup>184</sup> Panvini 2001, 20; the writer seems uncertain of the material, referring to the nails as "copper or iron."

<sup>185</sup> Pomey et al. 2012, 292.

frames.<sup>186</sup> The 1<sup>st</sup>-century B.C.E. shipwreck at Cap del Vol had iron nails reinforcing the garboard to the posts and in attaching the planks,<sup>187</sup> and similar construction is found in the 2<sup>nd</sup>-century C.E. shipwreck at Grado, Italy, with iron and copper nails used concurrently.<sup>188</sup> Copper nails are used extensively to fasten edge-joined planks to the frames in Classical construction, and not until later, such as in the 4<sup>th</sup>-century C.E. Yassiada ship with iron nails used to hold the garboard strakes to the keel and the planking to the internal skeleton,<sup>189</sup> is there a noticeable shift in the trust of the Mediterranean shipwright in the iron fastener. The Kızılburun ship was constructed using pegged mortise and tenon joinery and reinforced with copper nails,<sup>190</sup> but no wood remains were found with iron nails still attached. It is therefore difficult to say what part the iron fastener played in regards to the construction of this particular vessel.

## UNIDENTIFIED OBJECTS

### *UN 1 and UN 2*

Four concretions comprising two objects (**UN 1** and **UN 2**) excavated upslope of the drums, were given the mapping prefix ABP while on the seabed. During excavation, they looked to be a system of pipes but formed no clear joins to one another (Fig. 3.18). Upon inspection at the surface, **UN 1** (Lot 152) had a small footed ceramic bowl concreted to one surface, and **UN 2** (Lots 177 and 177.01) had a complete copper nail

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<sup>186</sup> Carrazé 1977, 302.

<sup>187</sup> Foerster 1980, 248, Fig. 10.

<sup>188</sup> Beltrame and Gaddi 2007, 141-2.

<sup>189</sup> Bass and van Doorninck 1971, 29-34.

<sup>190</sup> Carlson and Hamilton 2009, 13.

concreted to it. Lot 177.02 appeared to be related but its direct connection to the other portions of **UN 2** remains unclear.

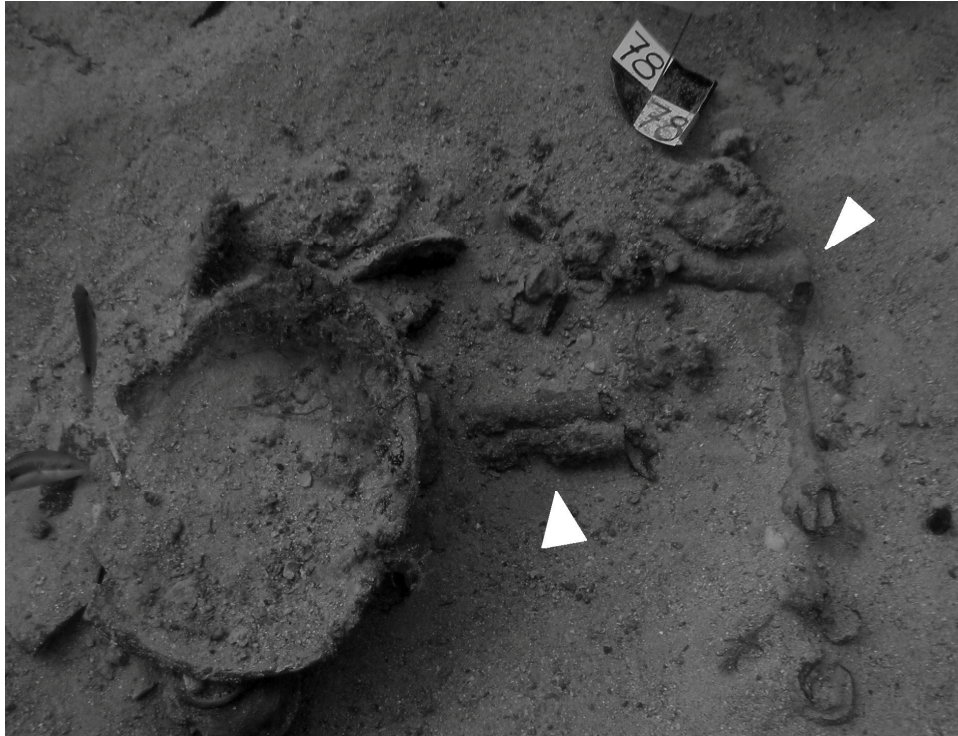


Fig. 3.18: **UI 1** (left) and **UI 2** (right) on the seabed (photo by S. Matthews). The mapping flag in the background, marked '78,' is a 10.0 cm square providing a scale for measure.

When the artifacts were transported to the laboratory in Bodrum, x-rays were taken, and it was clear that the ceramic bowl and copper nail were unrelated to the structure of the iron object and were carefully separated.<sup>191</sup> Casting of the remaining three portions continued easily, as breaks were sealed with plasticine and epoxy poured inside. **UN 1**

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<sup>191</sup> An x-ray of Lot 177.02 revealed no iron remains; however a lead fishing weight was discovered and separated before the remaining concretion was discarded.

and **UN 2** were cleaned with an air scribe, keeping a portion of the concretion intact at each broken extremity with the hope that other concretions might be identified as being a continuation of the object. There were also organic remains found in the V-shape formed by the lower portion of **UN 1**, and the concretion was kept surrounding them so that samples could be taken and identified. The two objects are identical in shape: the upper portions are formed by two parallel rods, cylindrical in section, and the lower portions are formed by two arms, rectangular in section, at a 90° angle from the rods. The two arms curve toward each other, but it is impossible to say that they were once attached to form a loop, since both are broken and no further connection can be made between **UN 1** and **UN 2** (Fig. 3.19).

Although at this time, the identities of **UN 1** and **UN 2** remain unknown, it can be deduced that the object may have played some role in the galley activities of the ship, given its context among seemingly personal objects of the crew, like the bowl and fishing weight, and within the immediate area another bowl and amphora sherds. It was also in this general area of the excavation that many amphoras were located. One object excavated from the remains of two Roman shipwrecks in Israel shares some of the same characteristics. An iron tripod, constructed of three rectangular bars joined together was uncovered, measuring 15.0 cm in height and 24.0 cm across, and could have been used to hold a pot over an open fire for cooking. The three legs were made of parallel

cylindrical rods attached at each junction of the rectangular bars.<sup>192</sup>



Fig. 3.19: UN 2 (left) and UN 1 (right) after casting.

One curious detail of the Kızılburun object is that if it represents a tripod, only two of the legs are preserved, and the rectangular arms appear to curve back together, so it is still unclear how UN 1 and UN 2 are truly related. Additionally, the iron rods were

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<sup>192</sup> Galili et al. 2010a, 78-9.



almost aligned in situ, leading one to believe that they would have been attached to form one object, with two parallel central rods and two arching rectangular bars at either end. At this stage, **UN 1** and **UN 2** do not match exactly the description for a tripod. Another consideration is that this equipment might represent a portion of a pumping system designed to remove water from the bilge. However, research into such devices reveals that contemporaneous examples were made of wood, bronze, and lead, but none has been reported as containing any iron components.<sup>193</sup> Since **UN 1** and **UN 2** are incomplete, the original shape and size are inestimable, as is any idea of missing components.

### *UN 3*

Two separate concretions (Lots 396 and 497) that join were found in two separate seasons. Since the concretion was broken, the internal cavities were full of sand, and the original surface of the object was not well-preserved. The cast produced is an iron rod (**UN 3**) with a cylindrical cross-section, perhaps a type of large iron fastener, such as a bolt, but because the extremities of the cast are misshapen, it is not possible to say definitively. There are also no wood remains attached to it, as is usually found with fasteners. Bolts were introduced as a means to reinforce the hull by fastening the frames to the keel during the Hellenistic era and became common practice by the 2<sup>nd</sup> century C.E., as evidenced by several shipwrecks of that century and later. At first bolts were

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<sup>193</sup> Marlier and Sibella 2002, 166-9, Figs. 11-12; Foerster 1980, 245 Figs. A-B; Foerster 1984; Schiøler and Garcia-Diego 1990; Kapitän 1983.

made of copper, and it was not until the 4<sup>th</sup> century C.E., that copper was replaced almost entirely by iron;<sup>194</sup> therefore it is unlikely that **UN 3** is an iron bolt.



Fig. 3.20: Some of the many fragments of **UN 4**, none of which joined (top), and the cross-section of the largest fragment, showing four separate thin rectangular objects (bottom).

#### *UN 4*

Deep in the sand beneath the toe of an amphora east of the drums, the author excavated a delicate iron concretion (Lot 618) in very poor condition (Fig. 3.20). It proved difficult

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<sup>194</sup> Pomey et al. 2012, 236-7.

to reconstruct the object (**UN 4**) after it was raised, since it continued to disintegrate upon further handling. Following removal from the seabed, there were two main portions of the concretion that were cleaned and cast. The larger of the two contained four thin, rectangular iron strips, and the smaller seems to be a continuation of it, consisting of two strips lying parallel to each other and connecting at one end (Fig. 3.21). None of the bars has striations to suggest that they are files or rasps. Since none of the four separate objects is complete, it is impossible at this time to identify their purpose. The concretion holding the four pieces together was kept in place in order to retain the spatial relationship between the objects.



Fig. 3.21: **UN 4** after casting.

## UN 5

Three large concretions unearthed in 2007 form one continuous shank-like object (UN 5) measuring 94.5 cm in length. Lot 733 forms one end of the object, Lot 713 the central section, and Lot 605 the other end, at which point the concretion is broken. The object has a squared cross-section throughout Lots 733 and 713, measuring approximately 3.0 cm by 3.5 cm, but at the very end of Lot 605, it flares to a wider section measuring 5.3 cm by 3.5 cm (Fig. 3.22). The object is definitely not a second iron anchor, and given the attributes that can be distinguished, it is not an anchor stock. There are substantial wood remains, closely resembling planking, attached to the middle section, but no copper nails were visible, and there are two large amphora body sherds concreted to it.

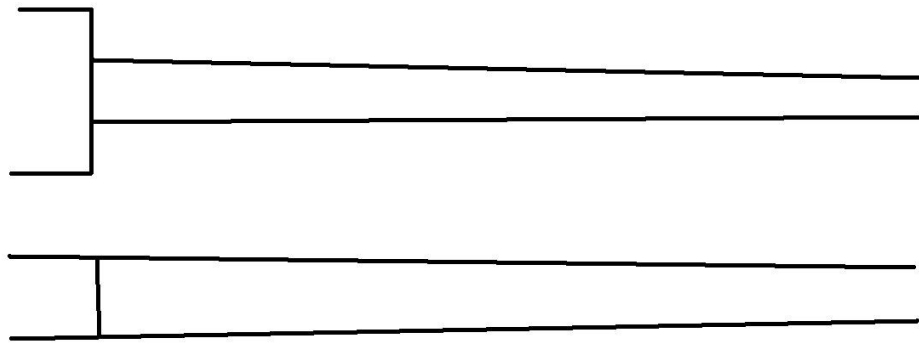


Fig. 3.22: Drawing of UN 5 derived from shape of metal cavity. Original shape of ends is unknown.

The reattachment of Lots 713 and 733 was straightforward, but when an attempt was made at joining the remaining section, it became more difficult. The break was not clean, and the pieces did not join neatly. First, epoxy was poured into Lot 733, followed

by the attachment of Lot 713 using plasticine as a bridge. Once the epoxy began to flow into Lot 713, it became evident that the concretion was not in good condition, possibly due to interference from the attached organic matter, and substantial leaks were visible. A best effort was made to plug the leaks while avoiding spilling epoxy onto the wood, but it proved difficult. It was decided in the end to leave the concretion in place, given the fragility of the wood and the likelihood of its disintegration while using the air scribe.

Recently, similarly shaped concretions were found on the Levanzo I shipwreck near Sicily. Dating to the 4<sup>th</sup> century C.E. due to the amphoras found at the wreck site, this ship carried two large iron bar concretions, one of which was raised. The preserved length measured approximately 1.5 m and the cross-section varied from 4.9 cm by 2.1 cm to 7.6 cm by 3.4 cm.<sup>195</sup> The authors compare the Levanzo I bars to iron ingots found on other shipwrecks; however, I am disinclined to agree with this assessment, given that the bar concretion also has an associated link chain preserved within it. Once the concretion from the Levanzo I shipwreck is cast, its purpose may be revealed, which may in turn provide an identity for the large Kızılburun concretion.

#### *UN 6*

**UN 6** was a small concretion (Lot 892.01), broken at one end, and found upslope of the drums. Epoxy was simply poured into the break to fill the internal cavity. At the break,

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<sup>195</sup> Royal and Tusa 2012, 44-6, Fig. 13.

the object appears to have been attached to a cylindrical rod, judging from the change in cross-section. The object flares slightly toward the preserved end, which is flat. Sloping upward from the flattened terminus are two ridges running parallel, growing taller and thus deepening the groove between them, giving it the very rough appearance of a gouge, although no gouges were found to mimic this shape (Fig. 3.23). It was also surmised that this small object might be a wedge or plug used to separate stone slabs in a quarry, but it does not match Rockwell's description of having a V-shaped section, nor is it robust enough to receive a blow from a mallet.<sup>196</sup>



Fig. 3.23: UN 6 after casting.

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<sup>196</sup> Rockwell 1993, 34-5, Drawing 1.

## DISCUSSION

The collection of tools from Kızılburun, although not found neatly in a basket as were the woodworker's tools from both the Ma'agan Michael and the Serçe Limanı shipwrecks,<sup>197</sup> may have belonged to an individual charged with hull repairs made mid-voyage. The fact that they were scattered over the site may be a result of the turmoil of the ship sinking or environmental activities in the area during the millennia following submersion. Given the absence of dedicated stonemason's tools, it does not appear that a mason was traveling with the Kızılburun cargo when it sank, although the flat chisel and nail remover may have been useful to a ship with a marble cargo. Since ancient ships were built primarily of organic material, from the moment a ship was launched, the crew was battling the forces of decay from practically all sides. For this reason, many ancient ships set sail with an individual on board capable of repairing the hull and performing routine maintenance to prolong the life of the vessel.<sup>198</sup> In his discussion of the tools found on the much later Serçe Limanı ship, Hocker states that more than likely, woodworking tools belonged to an individual instead of being a part of the ship's equipment, given the specialized nature of their handling and the expense of procuring them. A craftsman would likely have invested this much into his livelihood.<sup>199</sup>

Several ancient sources mention the necessity of making ship repairs during the course of a voyage, which further requires a skilled crewman or at least the proper equipment to

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<sup>197</sup> Udell 2003, 203; Hocker 2004, 314.

<sup>198</sup> Hocker 2004, 313.

<sup>199</sup> Hocker 2004, 320-1.

do so. Polybius recalled in the first treaty between Rome and Carthage that if a ship must put in to shore for repairs on foreign soil, the seamen can only take from shore anything needed to make the repair and depart within five days.<sup>200</sup> In such an emergency, it would be prudent to already be in possession of the necessary tools, given the treaty's limitations. Thucydides wrote that during a skirmish between the Athenians and Syracusans, damaged vessels were repaired while awaiting the Syracusans' next maneuver.<sup>201</sup> For this to be done quickly, the proper tools must have been at hand. Appian also mentioned the need for swift repair in the midst of an epic sea battle between Calvisius and Demochares during the Roman Civil Wars.<sup>202</sup> While these references are specific to wartime fleets, it still speaks to the necessity for a ship to be self-sufficient while at sea and the practicality of being prepared for emergencies. Even while not at sea, the author of the Athenian Constitution stated that a man must make the proper repairs to his ship or face penalties, which reinforces that it was not only financially beneficial but practical to have a crew member proficient in woodworking.<sup>203</sup>

Although most of the iron tools from Kızılburun have a clearer connection to woodworking, two of them, the flat chisel (**CH 1**) and the nail remover (**NR 1**) may have served multiple purposes aboard the marble carrier. The solid metal chisel has a proven use in stone working, and the nail remover as a type of prying device could be helpful in repositioning the smaller blocks and grave *stelai* in preparing for shipment. For these

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<sup>200</sup> Polyb. 3.22.4-7.

<sup>201</sup> Thuc. 7.38.

<sup>202</sup> App. *BCiv.* 5.9.84.

<sup>203</sup> Xen. [*Ath. pol.*] 3.4



reasons, it is likely that the iron tools from Kızılburun represent a collection specifically relevant to the shipment of stone in addition to being generally useful for necessary repairs and activities aboard the ship.

Tools were beloved by the tradesmen who used them. Woodworkers who could afford a finely-crafted tomb included depictions of their tools, like the *stèle* of Marcus Aebutius and the funerary relief of P. Ferrarius Hermes<sup>204</sup> both showing measuring tools, and the funerary relief of P. Licinius Philonicos and P. Licinius Demetrius, depicting an array of tools.<sup>205</sup> The fact that they are not commonly included in burials suggests that tools were passed down through the generations, being reworked and re-sharpened until they were ultimately scrapped. With any given tool, little regional variation is found throughout the territories of the Roman Empire,<sup>206</sup> making the British examples relevant for comparison. Due to the practices of purposeful burial and hoarding,<sup>207</sup> many well-preserved examples of tools have been found in Britain. A specific point of origin for those from Kızılburun cannot be determined, and it is impossible to perform analysis of the iron to determine its source, since no substantial metallic remains were extant for the majority of the artifacts.<sup>208</sup>

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<sup>204</sup> Ulrich 2007, Figs. 3.1 and 3.4.

<sup>205</sup> Ulrich 2007, Fig. 3.20.

<sup>206</sup> Ulrich 2007, 13-14.

<sup>207</sup> A chest full of various metallic objects was found at Corbridge, United Kingdom beneath the floorboards of a former fort in an attempt to hide valuables in light of the advancement of an enemy force (Daniels 1968, 125-6), a similar circumstance to the burial of the Inchtuthil hoard (Manning 1966, 3-4). Herodian wrote of the high value of iron to the natives in Roman Britain (Hdn. 3.14.7).

<sup>208</sup> Katzev (1982, 265) noted the same problem with the tools from the 7<sup>th</sup>-century Yassiada shipwreck, as does Hocker (2004, 297 and 314) with those from Serçe Limanı.

## **CHAPTER IV**

### **CONCLUSION**

Reconstructing iron objects from a shipwreck requires specialized skills and knowledge of the material. Iron concretions hold within them the potential for a better understanding of tools paramount to the safety of a voyage as well as equipment necessary to the ship. For this reason, solid judgment is required by archaeologists during excavation when raising artifacts from the seabed, and former experience with such objects is beneficial to the conservator charged with revealing their true identities. While the replication of iron artifacts lost to corrosion is a relatively uncomplicated process, it still requires thorough comprehension and publication of proper technique in order to prevent harm and the loss of information. Proper assessment in the laboratory begins with radiography, followed by documentation of the concretion in its initial state. From that point, the conservator must understand the concepts and chemicals involved in replication, since an iron object is generally reduced to a cavity within encrustation, which serves as a mold to recreate its form. The process remains the same whether the artifact is as small as a nail or as large as an anchor: epoxy resin is used to fill the empty void, and the rock-like exterior is chipped away to reveal a realistic facsimile of a once-iron object.

In the case of the smaller concretions from the Kızılburun shipwreck, casting was very basic. Rather than being cut open, which leaves a gap between the separated sections,

concretions were broken, so that the fragments could be joined neatly together. Once the sections were filled with epoxy resin, they were reconnected, and the epoxy was allowed to harden. Afterwards, the surrounding concretion was removed using an air scribe, and in cases where the black corrosion residue did not tint the epoxy, the replica was painted to resemble iron.

Casting the anchor, however, required creativity and problem-solving. For such a large object, I worried that the epoxy cast would not be strong enough to withstand handling, mounting, or even moving. A brass rod was chosen for reinforcement due to it being less susceptible to corrosion than iron, cheaper than stainless steel, and it could be easily cut to size. The rod was inserted before filling with epoxy resin in order to reinforce the cast of the anchor shank from inside. In addition, while the other concretions could be easily handled and checked for leaks prior to joining, many of the anchor concretion's sections were open at both ends, which made it difficult to assess them prior to attachment. For this reason, resin was poured in successive batches, so that leaks could be stopped before all the epoxy was lost. Regardless, many leaks appeared during pouring, and though each was successfully addressed, it would have been beneficial to coat the outer surface with a consolidant to prevent excess spillage and stress for the conservator.

In the scope of conservation, reconstructing ironwork from concretions is one of the fastest processes from initial assessment to the final steps of painting the cast in

preparation for display. As opposed to the years it can take to conserve metallic iron, as described for **AX 1**, or to stabilize the delicate, waterlogged wooden hull that any nautical archaeologist hopes to find, concretion casting can be completed in a matter of days. It is a very small investment in time, when considering what kind of information can be gathered from such artifacts. The iron objects from Kızılburun, brought to the surface by divers intuitive enough to question the presence of strangely shaped ‘rocks’ on the seabed, represent implements necessary to the ship’s crew.

The collection of iron objects from the late Hellenistic shipwreck at Kızılburun include: (a) an anchor, its associated stock, and one of its rings, (b) an anchor tooth for a wooden anchor, (c) two types of chisel, (d) a nail remover, (e) an axe-adze, (f) two double axes (one of which is probably intrusive), (g) three ship’s fasteners, (h) an iron bar, (i) and six other objects, the identities of which have yet to be determined. A catalog is included as an appendix to this thesis so that in the future, other objects of similar description may elucidate the identities of the six curious objects from Kızılburun. These artifacts represent tools and equipment essential to a ship in the Late Hellenistic Period, and in studying them, we can compare this assemblage to others and observe which objects evolved in form and continued to be of use.

The iron anchor, complete with stock and ring, is an extraordinary find in itself, but even more so given its context alongside wooden anchors on the same vessel. The concurrent use of iron and wooden anchors spans nearly 600 years and is represented by finds from

about two dozen shipwrecks, with at least 17 dating between the 2<sup>nd</sup> century B.C.E. and the 1<sup>st</sup> century C.E.<sup>209</sup> During this time frame, a pattern occurs in that several shipwrecks had a single iron anchor and multiple wooden ones,<sup>210</sup> which is mirrored on the late Hellenistic Kızılburun ship. At Kızılburun, two lead anchor stocks, one removable and one fixed, attest to the presence of at least two additional wooden anchors, and three lead collars suggest that there was probably a third. The coexistence of the three different types of anchor (a removable lead-stocked, a fixed lead-stocked, and an iron anchor) on the same vessel has not been previously recorded for another ancient ship. The fixed-stock anchor may have hung from the bow, since the permanently attached stock prevented it from lying flat on deck, from where it could be deployed quickly. The other wooden anchor and the iron anchor, both able to lie flat due to removable stocks, could be used as a backup in case a problem occurred with the main anchor. Lamboglia noted that the complement of seven anchors, four wooden and three iron, found at the 2<sup>nd</sup>-century B.C.E. shipwreck at Punta Scaletta, Italy were intended for different purposes and circumstances that may arise in the course of a longer voyage,<sup>211</sup> such as the need for multiple anchors in mooring, or varying bottom conditions which may warrant employing one type of anchor over another.<sup>212</sup> This may account for the multiple types and sizes of the anchors on the Kızılburun ship.

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<sup>209</sup> Information gathered from Parker 1992.

<sup>210</sup> Dramont C, 2<sup>nd</sup> cent. B.C.E. and Cap Gros C, 1<sup>st</sup> cent. B.C.E. (Parker 1992), Cap Taillat, 100 B.C.E. (Joncheray 1987, 139-43); Planier E, 100-50 B.C.E. (Benoit 1962, 156); Capo Testa B 75-25 B.C.E. (Gandolfi 1986, 81); and Grand Rouveau, 1<sup>st</sup> cent. C.E. (Liou and Corsi-Sciallano 1985, 65).

<sup>211</sup> Lamboglia 1964, 252-7.

<sup>212</sup> Campbell 2012, 415-6.

The iron anchor has an estimated weight of 38.5 kg (84.9 lbs), and the largest lead anchor stock weighs 105.72 kg (233.1 lbs), compared to 34.32 kg (75.7 lbs) for the smaller stock. The large marble elements of the Kızılburun cargo weigh an estimated 51.31 – 57.56 tons,<sup>213</sup> and even though it does not include the weight of the small marble blocks or the amphoras, the weight falls well within the capable range of either of the wooden anchors. The iron anchor, however, being much lighter may have been a secondary anchor to be used concurrently with one of the other two. Its size may also explain why it was still stowed at the time of sinking; such a light anchor would not have been helpful in steadying this particular troubled ship. Haldane examined eight shipwrecks with regards to the size of the associated lead anchor stocks in comparison to the size of the ship,<sup>214</sup> but his study did not verify a solid correlation between a ship's length and the length of its anchor stock. He did not explore a connection between estimated cargo weight and stock weights, but the varying tonnage of the vessels in his study as well as the varying weights of the stocks suggest that there is no ascertainable connection between the two, as even modern ship handling manuals advise. Although the size and tonnage of a ship may dictate somewhat the required weight of an anchor, an anchor's holding capability is not solely determined by its weight and design.<sup>215</sup> The efficacy of the anchor is governed by other factors including the strength of the cable used, the applied load, and the sediment conditions on the seabed,<sup>216</sup> which can be

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<sup>213</sup> Carlson and Aylward 2010, Table 2.

<sup>214</sup> Haldane 1984, App. 2.

<sup>215</sup> House 2007, 80.

<sup>216</sup> Vryhof Anchors B. V. 2010, 25-30.

evaluated using a sounding lead with tallow to collect a sample,<sup>217</sup> an example of which was also found at Kızılburun.<sup>218</sup>

An iron anchor from the 1<sup>st</sup>-century C.E. shipwreck at Grand Rouveau in France was found in similar circumstances as that from Kızılburun. It was also discovered in conjunction with two lead stocks, indicating the presence of two additional wooden anchors. Despite its significantly larger size (2.98 m in length compared to 1.64 m for AN 1), this iron anchor was also stowed at the time of sinking, indicated by the impression of planking left in its concretion.<sup>219</sup> Even though its weight must have been substantial enough to be of use to the ship wrecked at Grand Rouveau, the iron anchor still appears to be considered secondary to the wooden ones. On the other hand, Kapitän suggests that removable stocks were inadvertently useful as a type of lever and often became permanently separated from the anchor, a characteristic which resulted in the eventual abandonment of anchors with removable stocks.<sup>220</sup> It is a practical reason that may explain the absence of an affiliated anchor stock at Grand Rouveau and why the anchor had not been used on that vessel, as opposed to being of lighter weight like the anchor from Kızılburun. The common habit of anchors being snagged by fishing nets and lines must also be considered as a reason for missing anchor components.

Many ancient shipwrecks, from the Bronze Age to the Byzantine period, have been

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<sup>217</sup> Galili et al. 2009, 348-51; Oleson 2008, 121-4.

<sup>218</sup> Carlson 2005, 7, Fig. 9.

<sup>219</sup> Liou and Corsi-Sciallano 1985, 65.

<sup>220</sup> Kapitän 1984, 43.

found with different types of tools, not all of which are direct parallels for those from Kızılburun. However, shipboard tool kits indeed share a common purpose: the necessity for useful hand tools in a fairly isolated environment where an emergency may arise. Woodworking tools, such as the axe and axe-adze, were valuable in cases where repairs to the hull were urgent. The flat chisel and nail remover, while certainly effective in woodworking, may in fact have been multiple purpose tools, particularly useful on a ship with a primary cargo of marble. The drums were resting atop smaller blocks found along the port side of the keel, which begs the question: who was responsible for shaping and lading these stones, the stonemasons more familiar with marble or the sailors more knowledgeable in lading the ship? It would indeed be prudent to have a flat chisel on board in preparing a marble shipment, and a crew member might have been capable of shaping a block to fit his needs. The cargo of other rough cut blocks and grave *stelai* were small enough to be lifted without special equipment, and the nail remover would have been useful as a prying device to lift a block enough away from a flat surface in order to insert a hand or strap.

For most shipwrecks with iron tools, at least one bladed instrument is among them, and it can be deduced easily that an axe or axe-adze is a tool with various applications. In making repairs to the hull or rigging, or even collecting firewood on shore for cooking, the uses of bladed instruments in antiquity were just as varied as they are today. On the



other hand, the nail remover, only found on one other shipwreck,<sup>221</sup> had specific applications, and its inclusion in the shipboard tool kit must have been eclipsed by other tools, such as the claw hammer, which has inherent benefits over a tool that only has the capacity to remove nails.

The late Hellenistic marble carrier at Kızılburun is especially significant because both the origin of the cargo and its destination have been established. The tools and anchors found on this shipwreck were chosen because of their usefulness to the crew. Although the types of tools available in the Late Hellenistic Period were numerous, it is clear that only a handful were selected for their importance to any given voyage. Additionally, a captain outfitting his vessel could select from different anchor styles. Questions and answers regarding these choices are still evolving, and as more shipwrecks are excavated, there is always the hope that we can better understand the necessary equipment of ancient ships, thus expanding our view of seafaring in antiquity.

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<sup>221</sup> Nieto et al. 1989, 212.

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## APPENDIX A

### CATALOG OF IRON OBJECTS

#### AN 1. Iron Anchor (Lots 205, 261, 283, and 367)

L: 163.8 cm	W. Shank: 3.2 cm
TH. Shank: 3.6 cm	Arm Span: 69.2 cm
L. Crown: 4.0 cm	Dia. Crown Aperture: 1.8 cm
L. Right Arm (ABX-2): 43.8 cm	L. Left Arm (ABX-3): 42.2 cm
L. Right Tooth: 4.0 cm	L. Left Tooth: 6.1 cm
L. Stock Aperture: 7.0 cm	W. Stock Aperture: 4.6 cm
TH. Stock Aperture: 4.1 cm	Dia. Ring Aperture: 3.6 cm
W. Head: 6.0 cm	TH. Head: 1.0 cm
W. of Rectangular Section at Juncture of Arms: 11.0 cm	
TH. of Rectangular Section near Juncture of Arms: 2.0 cm	
Est. Original Weight: 22.8 kg	

Epoxy cast of intact iron anchor stowed at time of ship's sinking. Distinct V-shape in arms. Found in area 20.

#### *Parallels*

Two iron anchors, Roman shipwreck, Ashkelon, Israel, 2<sup>nd</sup> – 1<sup>st</sup> cent. B.C.E. (Galili et al. 2010b). Arms come out straight from the crown and then curve upward, as a variation of the V-shape seen in the other parallels.

Iron anchor, Isla Pedrosa shipwreck, Spain, 2<sup>nd</sup> cent. B.C.E. (Foerster 1969).

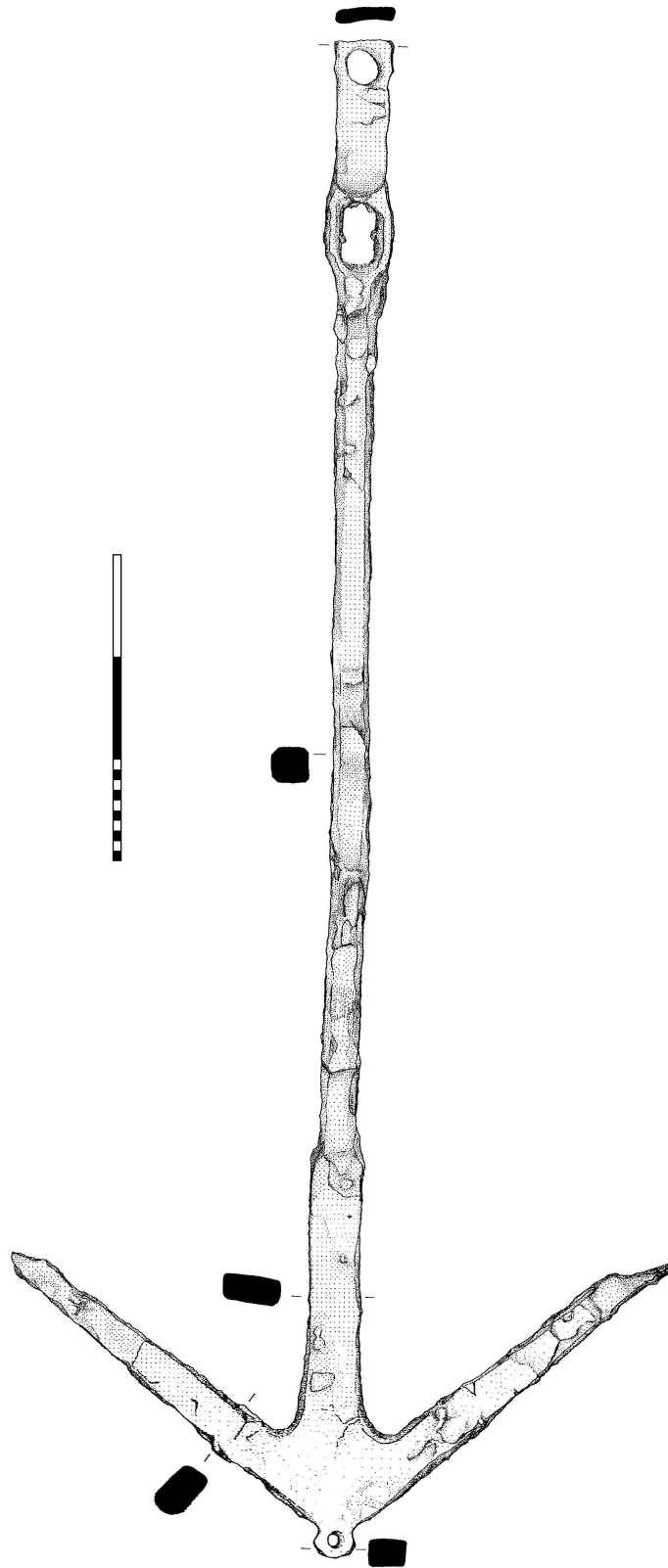
Iron anchor fragment La Ciotat shipwreck, France, 2<sup>nd</sup> cent. B.C.E. (Benoit 1958).

Three iron anchors, Punta Scaletta shipwreck, Italy, 2<sup>nd</sup> cent. B.C.E. (Lamboglia 1964).

Iron anchor, Cap Taillat shipwreck, France, 100 B.C.E. (Joncheray 1987).

Iron anchor, Capo Testa B shipwreck, Italy, 1<sup>st</sup> cent. B.C.E. (Gandolfi 1986).

Iron anchor, Grand Rouveau shipwreck, France, 1<sup>st</sup> cent. C.E. (Liou and Corsi-Sciallano 1985).



App. 1: AN 1.

**ST 1.** Iron Anchor Stock (Lots 370, 386, and 387)

L.: 130.9 cm	W. at A: 5.5 cm	W. at B: 5.9 cm
W. at C: 6.5 cm	TH. at A: 2.0 cm	TH. at B: 3.9 cm
TH. at C: 1.6 cm	Dia. of Pin Hole: 1.1 cm	
Est. Original Weight: 15.7 kg		

Epoxy cast of removable iron anchor stock found associated with iron anchor (**AN 1**). Hole for attachment pin exists but no evidence of pin or attachment. Found in area 20.

*Parallels*

Although several iron anchors of this type have been described, few have been located with their associated stocks. The Ashkelon anchor stocks, 2<sup>nd</sup> – 1<sup>st</sup> century B.C.E. are similar in style, but they are not an exact parallel. The steps on both stocks are parallel to the stock itself (Galili et al. 2010b), while the step on the Kızılburun stock is perpendicular.



App. 2: **ST 1.**



**ST 1.** Iron Anchor Stock (cont.)

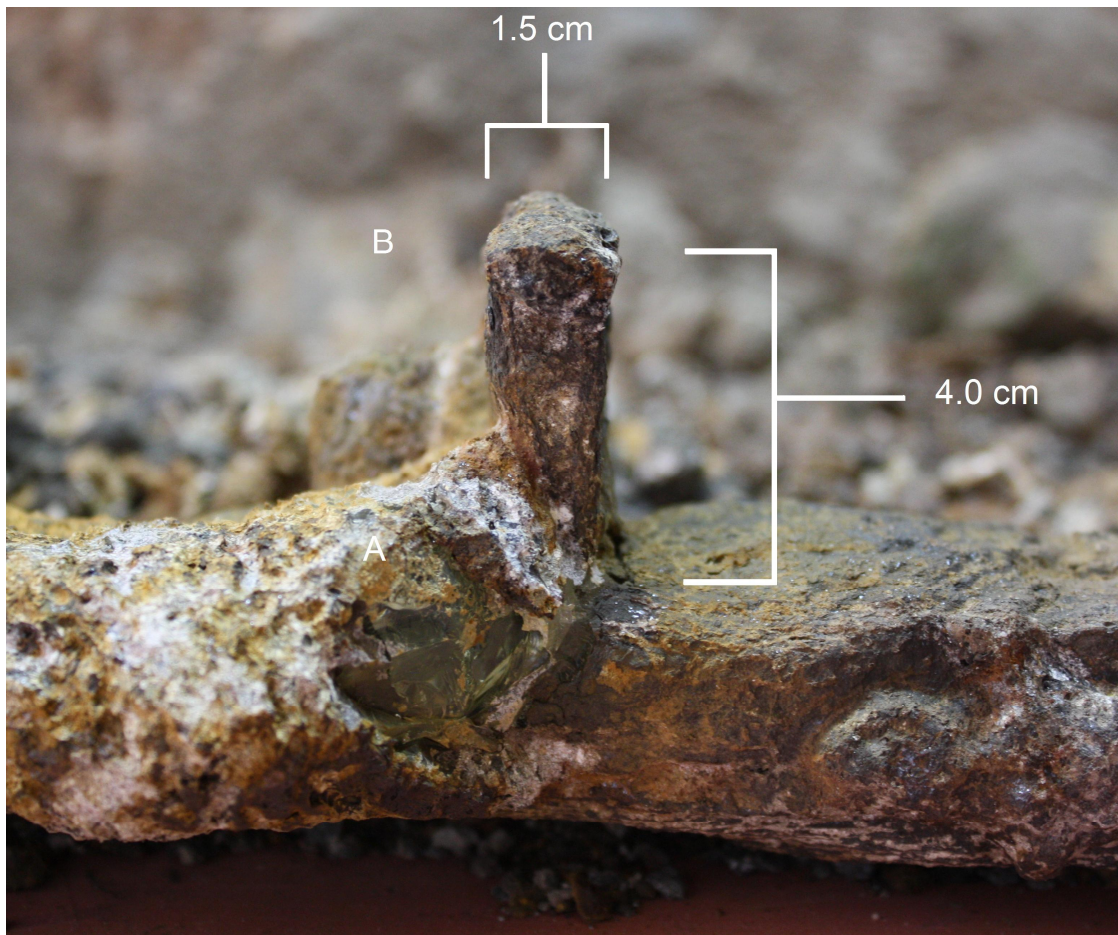
*Dimensions of Step*

H.: 4.0 cm

TH.: 1.5 cm

W. at A: 4.8 cm

W. at B: 5.5 cm



App. 3: **ST 1** – Detail of step.

**AR 1.** Iron Anchor Ring (Lot 311)

Est. Dia.: 14.0 cm

Preserved L.: 12.0 cm

Preserved W.: 1.0 cm

Epoxy cast of partial upper ring for attaching cable to iron anchor (**AN 1**). Found in area 20.

*Parallels*

Two iron rings from two two-armed anchors, and a partial ring from one-armed anchor, all from Ashkelon, Israel, 2<sup>nd</sup> – 1<sup>st</sup> cent. B.C.E. (Galili et al. 2010b).



App. 4: **AR 1.**

**AT 1.** Iron Anchor Tooth (Lot 621)

L.: 28.0 cm

W.: 3.8 – 9.0 cm

Depth of grooves along top surface of tooth: 0.9 cm

Epoxy cast of tooth intended as reinforcement for the arm of a wooden anchor. Found in area 18, near lead anchor stock (Lot 825).

*Parallels*

One iron anchor tooth, Tour-Fondue shipwreck, France, 3<sup>rd</sup> cent. B.C.E. (Joncheray 1989)

Two iron anchor teeth, Chrétienne C shipwreck, France, 2<sup>nd</sup> cent. B.C.E. (Joncheray 1975a)

Two iron anchor teeth, Lake Nemi, Italy, 1<sup>st</sup> cent. C.E. (Speziale 1931).



App. 5: AT 1.

**CH 1.** Flat chisel (Lots 117.01, 150.02, and 790.01)

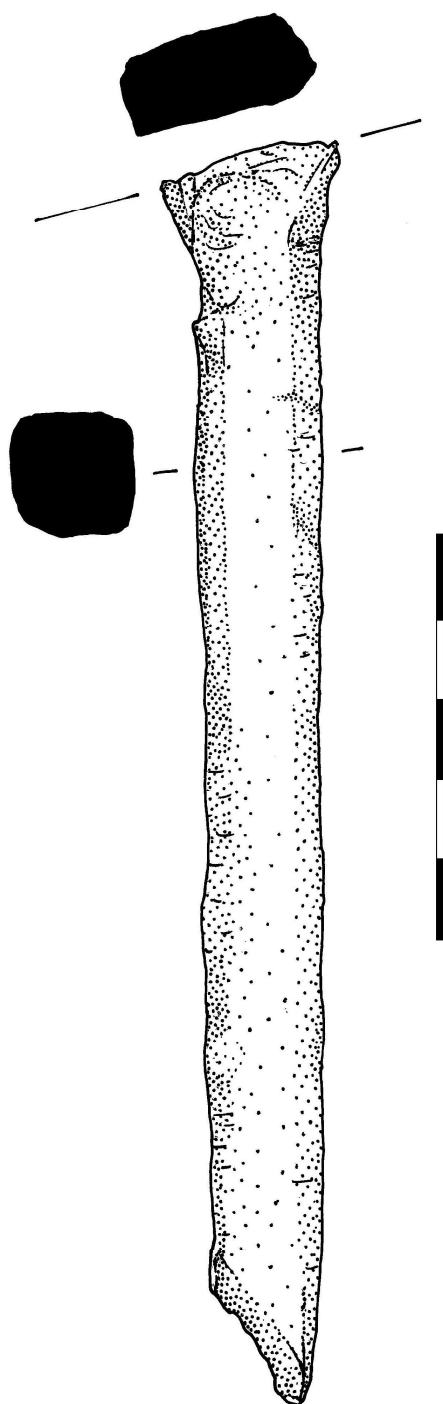
Min. L.: 28.6 cm	W. Shaft: 1.4 – 2.1 cm	TH. Shaft: 1.0 – 1.4 cm
W. Handle: 2.0 cm	TH. Handle: 2.0 cm	W. Blade: 2.0 – 3.1 cm
TH. Blade (Visible Original Surface): 0.5 cm		

Epoxy casts of three fragments of iron chisel: handle (150.02), shaft (117.01), and blade (790.01). Found in area 18 (shaft and blade) and area 19 (handle).

*Parallels*

Flat chisel for stone working, Porto Novo shipwreck, Italy, 1<sup>st</sup> cent. C.E. (Bernard et al. 1997).





App. 6: **CH 1** – Shaft, handle, and blade (clockwise).

**CH 2.** Bar Chisel (Lot 322.05)

L.: 37.7 cm

W.: 0.3 – 3.3 cm

TH.: 0.2 – 1.1 cm

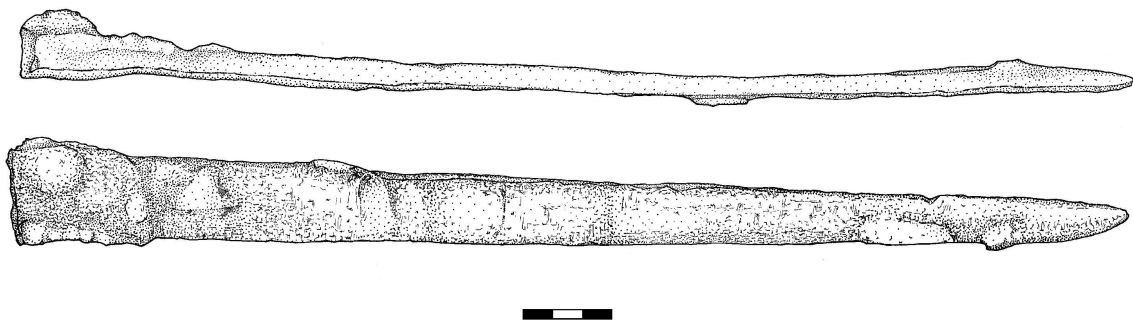
Epoxy cast of tapered iron bar with rectangular cross-section, ending in a point. Found in area 17.

*Parallels*

Chisel/wedge, Saalburg, Germany, 2<sup>nd</sup> cent. C.E. (Pietsch 1983).

Chisel/blade, Pompeii, Italy, 1<sup>st</sup> cent. C.E. (Allison 2006).

Three deep-bar chisels, Uluburun shipwreck, Turkey, 14<sup>th</sup> cent. B.C.E. (Pulak 1988)



App. 7: **CH 2.**

**NR 1. Nail Remover (Lot 741)**

L.: 17.3 cm	W. Handle: 2.1 cm	TH. Handle: 2.9 cm
Prong W.: 1.0 cm	Prong TH.: 0.5 – 2.6 cm	W. of Prongs: 3.2 – 3.5 cm
W. at Handle End: 3.9 cm		

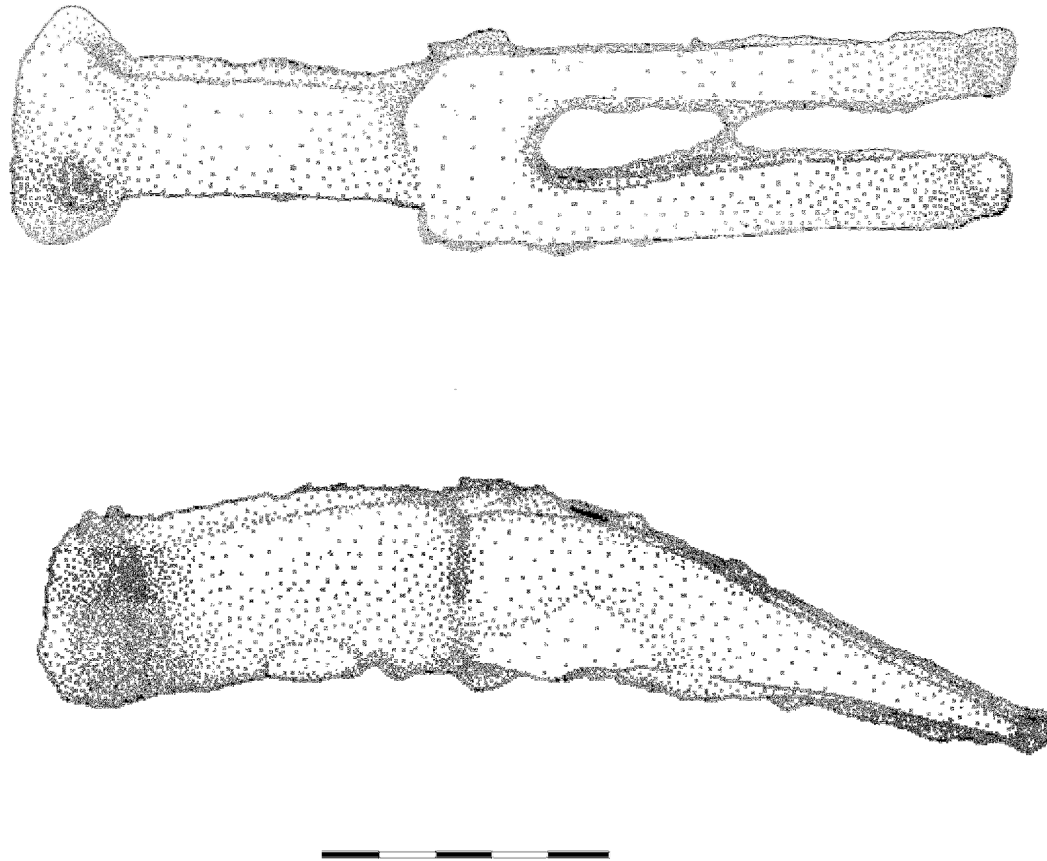
Epoxy cast of a clawed tool for removing nails from wood, or shortened form of crowbar. Found west of Drums 1 and 3.

*Parallels*

Nail remover, Pompeii, Italy, 1<sup>st</sup> cent. C.E. (Petrie 1917).

Nail remover, Cala Culip IV shipwreck, Spain, 1<sup>st</sup> cent. C.E. (Nieto et al. 1989).

Five nail removers, Saalburg, Germany, 2<sup>nd</sup> cent. C.E. (Pietsch 1983).



App. 8: NR 1.

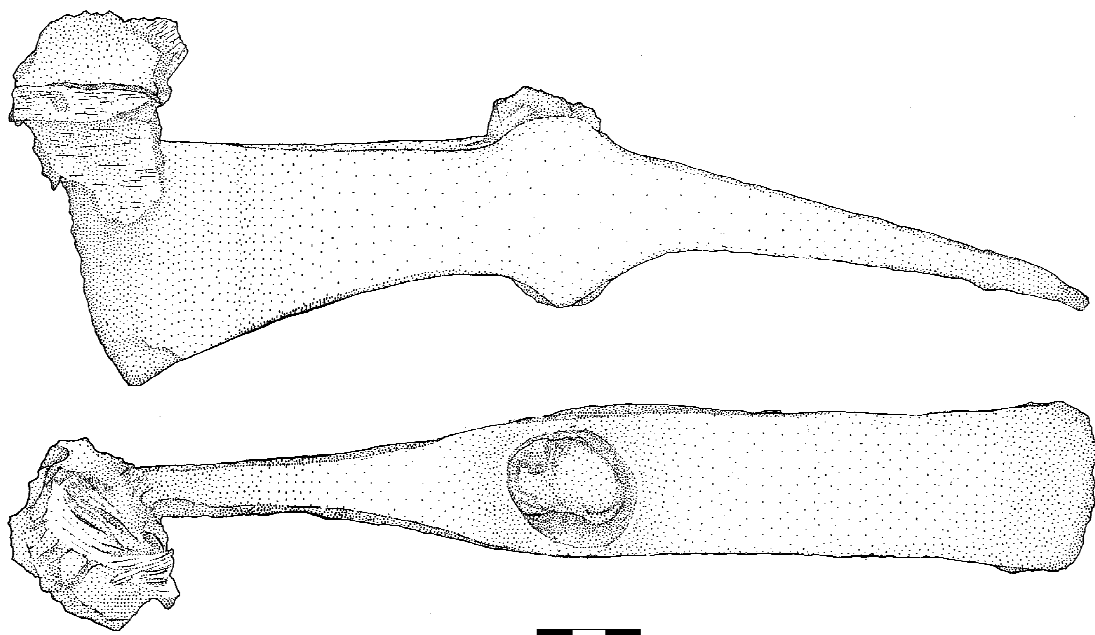
**AA 1. Axe-adze (Lot 190)**

L.: 30.9 cm	L. from Axe to Haft: 12.5 cm	W. Axe: 3.9 – 7.8 cm
TH. Axe: 0.2 – 3.6 cm	L. from Adze to Haft: 14.1 cm	W. Adze: 4.1 – 4.9 cm
TH. Adze: 0.2 – 3.2 cm	W. at Haft: 5.4 cm	TH. at Haft: 4.2 cm
Dia. Hole: 2.2 cm	W. Handle: 3.4 cm	
TH. Handle: 1.8 – 2.4 cm	Preserved L. Handle: 6.1 cm	

Epoxy cast of combination tool known as an axe-adze. Found in area 20.

*Parallels*

Axe-adze, Grand Ribaud A shipwreck, France, 2<sup>nd</sup> cent. B.C.E. (Carrazé 1975).  
Axe-adze, Chrétienne A shipwreck, France, 1<sup>st</sup> cent. B.C.E. (Dumas 1964).  
Two axe-adzes, Chrétienne J shipwreck, France, 1<sup>st</sup> cent. B.C.E. (Pomey et al. 1988).  
Axe-adze, Cap Gros C shipwreck, France, 1<sup>st</sup> cent. B.C.E. (Joncheray 1991).  
Axe-adze, Pompeii, Italy, 1<sup>st</sup> cent. C.E. (Petrie 1917).  
Five axe-adzes, Saalburg, 2<sup>nd</sup> cent. C.E. (Pietsch 1983).  
Axe-adze, Yassiada shipwreck, Turkey, 4<sup>th</sup> cent. C.E. (Bass and van Doorninck 1971).  
Two axe-adzes, Yassiada shipwreck, Turkey, 7<sup>th</sup> cent. C.E. (Katzev 1982).



App. 9: AA 1.



**AX 1.** Iron Double Axe (Lot 394)

L.: 28.5 cm                      W. Blade End: 9.0 cm                      W. at Handle: 5.2 cm  
W. Handle: 4.9 cm              Th: Undetermined due to concretion  
Preserved L. Handle: 12.3 cm

Metallic double axe with portion of wooden handle preserved. Found in area 19.

*Parallels*

Double axe, Chrétienne H shipwreck, France, 1<sup>st</sup> cent. C.E. (Santamaria 1984).

Two double axes, two shipwrecks, Ashkelon, Israel, 3<sup>rd</sup> - 4<sup>th</sup> cent. C.E. (Galili et al. 2010a).

Three double axes, Yassıada shipwreck, Turkey, 7<sup>th</sup> cent. C.E. (Katzev 1982).



App. 10: **AX 1.**

**AX 2.** Iron Double Axe (Lot 824)

L.: 19.5 cm	W. Blades: 7.5 – 8.4 cm	TH. Blades: 0.2 cm
W. at Haft: 1.9 cm	TH. at Haft: 3.1 cm	W. Handle: 2.7 – 3.5 cm
TH. Handle: 1.3 – 2.3 cm	Preserved L. Handle: 8.3 cm	

Epoxy cast of iron double axe with portion of handle preserved. Found west of site near Late Roman ceramics. Probably intrusive.

*Parallels*

Resembles more modern type of axe. Archaeological parallel not found.



App. 11: **AX 2.**

**FB 1.** Iron Bar (Lot 387.01)

L.: 23.5 cm

W.: 4.7 cm

TH.: 1.0 cm

Metallic flat iron bar concreted to underside of ABX-8 (Lot 387), terminus of iron anchor stock (**ST 1**). Appears incomplete but vaguely rectangular. Relationship with stock unknown. Also found lying directly atop a thin sheet of wood remains. Found in area 20. Function remains unknown.

*Parallels*

Closest parallel: Single iron bar, Cap del Vol shipwreck, Spain, 1<sup>st</sup> cent. B.C.E. (Foerster 1980).



App. 12: **FB 1.**



**FN 1.** Iron Nail (Lot 144)

L.: 8.8 cm

W.: 0.45 – 0.65 cm

Epoxy cast of fragment of iron nail with square cross-section. Found in area 18.

*Parallels*

Square section nails common and found throughout Roman provinces.



App. 13: **FN 1.**

**FN 2.** Iron Nail (Lot 655.04)

L.: 12.1 cm

W.: 0.9 cm

Epoxy cast of fragment of iron nail. Wood obscures cross-section; assumed square. Bent tip and associated wood remains concreted to the shaft indicate a used nail. Found in area 17.

*Parallels*

Square section nails common and found throughout Roman provinces.



App. 14: **FN 2.**



**FN 3. Iron Nail (Lot 950)**

L.: 8.8 cm

W.: 0.4 – 0.6 cm

Epoxy cast of iron nail fragment with square cross-section. Tapers toward tip. found in area 17.

*Parallels*

Square section nails common and found throughout Roman provinces.



App. 15: **FN 3.**

**UN 1. Unidentified Iron Object (Lot 152)**

L. Rods: 17.2 cm

Dia. Rods: 1.8 cm

L. Bars: 21.5 cm

W. Bars: 3.1 cm

TH. Bars: 2.2 cm

Epoxy cast of unknown object. Two parallel rods form a 90° angle with two curved rectangular bars. Found in area 20 with rods almost aligned with those of **UN 2**.

*Parallels*

No exact parallels found. Somewhat resembles iron tripod from two Roman shipwrecks, Israel, 3<sup>rd</sup> – 4<sup>th</sup> centuries C.E. (Galili et al. 2010a), but rectangular bars would not join to form triangle.



App. 16: **UN 1.**

**UN 2.** Unidentified Iron Object (Lots 177 and 177.01)

L. Rods: 13.9 cm

Dia. Rods: 1.8 cm

L. Bars: 26.0 cm

W. Bars: 3.0 cm

TH. Bars: 2.2 cm

Epoxy cast of unknown object. Two parallel rods form a 90° angle with two curved rectangular bars. Found in area 20 with rods almost aligned with those of **UN 1**.

*Parallels*

No exact parallels found. Somewhat resembles iron tripod from two Roman shipwrecks, Israel, 3<sup>rd</sup> – 4<sup>th</sup> centuries C.E. (Galili et al. 2010a), but rectangular bars would not join to form triangle.



App. 17: **UN 2.**



**UN 3. Unidentified Iron Object (Lots 396 and 497)**

L.: 32.5 cm

Dia.: 2.1 cm

Epoxy cast of probable iron fastener, perhaps a bolt, with round cross-section. Organic matter attached at one end. Two concretion fragments found upslope of drums and near Drum 1, respectively.

*Parallels*

Closest parallels: Iron bolts, Laurons 2 shipwreck, France, 2<sup>nd</sup> cent. C.E.

Pointe du la Luque B shipwreck, France, 4<sup>th</sup> cent. C.E.

Yassiada shipwreck, Turkey, 4<sup>th</sup> cent. C.E.,

Dramont F shipwreck, France, France, 4<sup>th</sup> cent. C.E.

Fiumiucino 1 shipwreck, Italy, 4<sup>th</sup> – 5<sup>th</sup> cent. C.E.,

Port-Vendres I shipwreck, France, 400 C.E. (All parallels, Pomey et al. 2012)



App. 18: **UN 3.**

**UN 4. Unidentified Iron Object (Lot 618)**

L. Bar 1: 15.1 cm	W. Bar 1: 1.0 cm	TH. Bar 1: 0.1 cm
L. Bar 2: 11.0 cm	W. Bar 2: 1.0 cm	TH. Bar 2: 0.1 cm
L. Bar 3: 4.8 cm	W. Bar 3: 0.7 cm	TH. Bar 3: 0.1 cm
L. Bar 4: 3.3 cm	W. Bar 4: 0.7 cm	TH. Bar 4: 0.1 cm
L. Bar 5: 8.1 cm	W. Bar 5: 0.7 cm	TH. Bar 5: 0.1 cm
L. Bar 6: 8.1 cm	W. Bar 6: 1.2 cm	TH. Bar 6: 1.4 cm
Distance between Bars 5 and 6: 1.4 cm		

Epoxy casts of a two groups of flat iron bars concreted together. Function and relationship unknown. Found in area 20.

*Parallels*

No known parallels found. Somewhat resemble files, but no serrations.



App. 19: UN 4.

**UN 5.** Unidentified Iron Object (Lots 605, 713, and 733)

L.: 94.2 cm

W. at 1: 5.6 cm

TH. at 1: 3.5 cm

W. at 2: 3.2 cm

TH. at 2: 3.5 cm

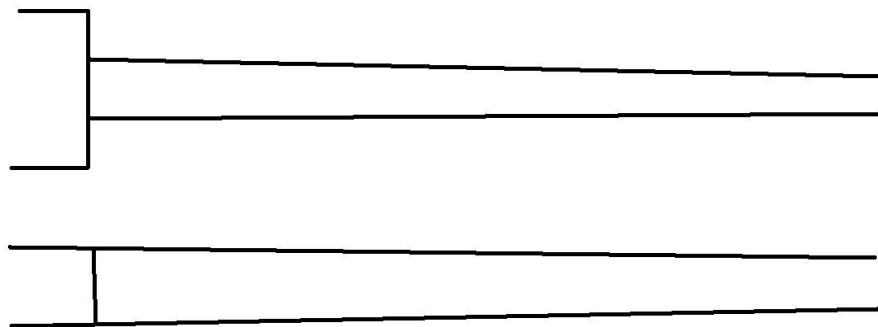
W. at 3: 3.3 cm

TH. at 3: 3.5 cm

Large iron bar concretion, wood remains attached. Identity unknown. Cross-section is square throughout, but at broken end, abruptly changes to rectangular section, with same thickness. Casting begun but not complete, due to wood remains and large fractures. Found in area 19.

*Parallels*

Iron bar concretion, Levanzo I shipwreck, Sicily, 4<sup>th</sup> cent. C.E. (Royal and Tusa 2012).



App. 20: **UN 5** – Concretion (top) and shape determined by inner cavities (bottom).

**UN 6.** Unidentified Iron Object (Lot 892.01)

L.: 4.1 cm

W.: 1.8 – 2.5 cm

TH.: 0.6 – 2.3 cm

L. Recess: 2.3 cm

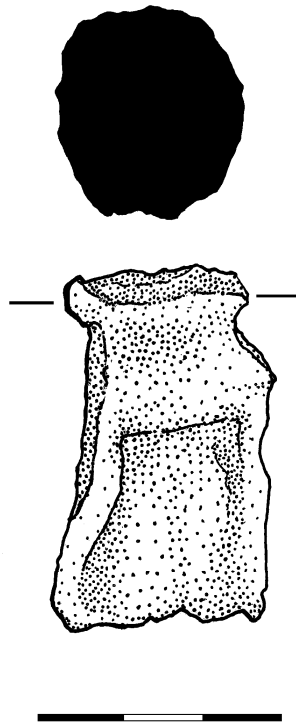
W. Recess: 1.1 – 1.8 cm

Depth Recess: 0.2 – 0.7 cm

Epoxy cast of incomplete small iron object whose identity remains unknown. Was once attached to circular rod, identifiable by cross-section at broken end. Found in area 20.

*Parallels*

No known parallels found. Somewhat resembles a gouge.



App. 21: **UN 6.**